BUILDING BRIDGES BETWEEN IDEAS AND MARKETS

FINAL REPORT

of the TSER-funded project:

Contract n": SOE1-CT98-1102
Project nr: PL 98.0230

Title: ***National Systems of Innovation and Networks in the Idea-Innovation Chain in Science based Industries***

Project Coordinator
Utrecht University, Research School for Social & Economic Policy Studies,
Prof. dr. Frans van Waarden,
Heidelberglaan 2, PO Box 80140,
3508 TC Utrecht, the Netherlands

Partners:
Technische Universitaet Muenchen, Lehrstuhl für Politische Wissenschaft
Prof. Edgar Grande,
Lothstraße 17, 80335 München, Germany

Vienna University of Economics, Institut für Volkswirtschaftstheorie und Politik,
Prof. Brigitte Unger,
Augasse 2-6, 1090 Wien, Austria

University of Tampere, Work Research Centre,
Prof. Gert Schienstock,
Tullikatu 6, PO Box 607, 33101 Tampere, Finland

Starting Date: December 1, 1998
Project Ended: November 30, 2001

Project funded by the European Community under the
Targeted Socio-Economic Research (TSER)

Table of Contents

Preface

The present report summarizes the findings of the project *National Systems of Innovation and Networks in the Idea-Innovation Chain in Science based Industries*, funded by the European Commission under the Fifth Framework Program 'Targeted Socio-Economic Research' (Contract Number SOE1-CT98-1102, project number PL 98.0230). It is a shortened version of a longer unpublished final report, which includes in its Annex also eight chapters on country-sector studies (the telecom and biotech sectors in Germany, Austria, Finland, and the Netherlands). These are themselves each 20 page summaries of longer studies on these two sectors in the countries mentioned, which have only appeared as manuscripts by the respective universities where the studies were done. Some of them have been reworked into other publications (e.g. the dissertation Oosterwijk 2003) and are hence separately accessible.

We would like to thank quite a few people, who in various ways contributed to this study. First and foremost the more than 150 people who know the telecom and biotech industries in these countries inside-out, because they are their daily life (at least while we interviewed them). They were generously willing to receive and devote time to us, answer our inquisitive questions patiently, and provide us often with additional written documents and other information. For reasons of privacy they have to remain the invisible shadows behind this study.

The report would also not have been possible without the researchers who have worked for the project at various points in time, in different countries, and on different topics. The teams were respectively made up of, in Austria: Martin Unger, Suzanne Giesecke, Stefanie Rossak, Herman Oosterwijk, and Brigitte Unger; in Germany Suzanne Giesecke, Robert Kaiser, and Edgar Grande; in Finland Mika Kautonen, Helena Tapper, Petri Honkanen, Anu Lyytinen, Pasi Tullki, Jorma Kuitonen, and Gerd Schienstock; and in the Netherlands Herman Oosterwijk and Frans van Waarden.

Thirdly, we would like to extend our thanks to the members of our advisory board, who accompanied us along the way with critical comments on our approach and later on the drafts that we then published. We were able to engage in lively exchanges with them during meetings of the board in Wassenaar, Vienna, and Amsterdam. We thank Tarmo Lemola, National Research Foundation VTT, Finland; Stefan Kuhlmann, Frauenhofer Institut für Systemtechnik und Innovationsforschung, Karlsruhe, Germany; Hansvolker Ziegler, Bundesministerium für Bildung, Forschung, Wissenschaft und Technik, Bonn; Wolfgang Polt, Joanneum Institute of Technology and Regional Policy, Vienna, Austria; Joseph Taus, Industriellen Vereinigung, Vienna; Svetlana Peytchova, Austrian Telekom, Austria; Dany Jacobs, Twente School of Management, Enschede, The Netherlands; Alfred Kleinknecht, Technical University Delft, the Netherlands; Jan Smits, Law and Technology, Eindhoven Centre for Innovation Studies, Technical University Eindhoven, the Netherlands; Enid Mante, KPN Research, The Hague, Netherlands; Rogers Hollingsworth, University of Wisconsin, Madison, USA; and Jerry Hage, Director Center for Innovation, University of Maryland, USA.

Fourthly, we thank inspiration to the members of the Innovation Theme Group, year 1998-99, at the Netherlands Institute of Advanced Studies in the Social Sciences and Humanities NIAS

in Wassenaar. They gave us lots of ideas at the start of this project: Rogers Hollingsworth (Madison, USA), Jerry Hage (University of Maryland), Richard Whitley (Manchester Business School), Steven Casper (Wissenschaftszentrum Berlin), Bart Nooteboom (then University of Groningen), Marius Meeus (Eindhoven University of Technology), and Ernst Homburg (Maastricht University).

Inspiration was also provided by the other participants of the opening conference, held at NIAS in 1999: Bengt-Ake Lundvall (University of Aarhus), David Soskice (Wissenschaftszentrum Berlin), Phil Cooke (University of Cardiff), Gerhard Fuchs (Academy for Technology Assessment, Stuttgart), Louis Pauly, David Wolfe (both University of Toronto), Ulrich Wengenroth (Technical University Munich), Rob van Tulder (Erasmus University Rotterdam), Yoshitaka Okada (Tokyo University), Margarita Turvani (University of Venice), Ulrike Hotopp (German Ministry of Technology, Bonn), Heide Hackmann (University of Twente), and Rudi van Zijp (Dutch Ministry of Economic Affairs, The Hague)

While the participants at the opening conference provided inspiration, those at the dissemination conference gave reflection on our findings from the side of industry. We profited from the insights provided by Markku Valtonen, Tampere Central Region EU-Office, Tampere, Finland/Brussels; Helmut Wendner, Datacom, Vienna; Gerald Fliegel, Siemens Austria, Vienna; Alexander von Gabain, Intercell, Vienna; Karl Kuchler, Wirtschaftsfoerderungsfonds, Vienna; Herdis Menhaardt, Wirtschaftsuniversitaet Vienna; Hans Schaffers, Telematica Institute, Enschede, Netherlands; Jann van Benthem, TOP program, Twente Technical University, Enschede, Netherlands; Joerg Wadzack, Human Genome Project, Berlin; dr Kopatzik, head of innovation in ICT, Siemens, Berlin.

Last but not least we would like to thank Virginia Vitorino from the European Commission, who so patiently followed our project and showed a keen interest by attending some of our workshops and conferences.

Summary

It has often been noticed that commercial innovative activity is not evenly spread across nations, that countries have different sectoral specializations, and that these tend to persist over time. Positions of leader or of laggard may be continued through further innovations in fields where one has a strong position. I.e. such sectoral specializations are part of the 'national system of innovation'. However, such path dependencies could be broken through radical innovations, which make existing knowledge obsolescent and hence existing competences less relevant. Have such changes provided 'windows of opportunity' to economies to escape from path dependency?

That is what our project set out to investigate: What have been the consequences of major paradigm shifts in two science-based industries: telecommunications and biotechnology? Have countries hit upon the 'windows of opportunity' they provided, and if so how? We have done so for four countries that have had historically different positions in these industries: Germany and the Netherlands, which both have long-standing electronics/ICT sectors and agro and pharma-industries (where biotech has made most inroads); furthermore Finland, which has neither but has managed to conquer a strong position in these industries, notably telecom; and finally Austria, which has neither, but has nevertheless managed to combine economic prosperity with low levels of innovative activity.

The sectors under study have experienced radical technological changes: in telecom the change from electro-mechanical to the optical-digital paradigm, which fortified a trend of privatization and market liberalization; in biotechnology the change from classical 'trial and error' biotechnology to modern biotechnology based on genomics. We investigated their consequences for:

- the organizational architecture of the idea-innovation chain in these industries.
- the performance of our countries: have these industries become more or less important?
- how national institutions that control the basic resources - knowledge, skills, and finance - have hindered or facilitated such organizational changes.
- how relevant the 'national' character of national systems of innovation still is.

We wrote extensive reports which traced the changes in these industries in the various countries over the last fifty years and how the paradigm changes have affected them. Here we summarize some comparative findings.

First of all, the country-sector cases exhibited a number of common trends:

As to the *nature of knowledge* involved:

1- the science-base of these industries has increased
2- knowledge from an increasing diversity of sciences has to be combined
3- single organizations - firms, private and public research organizations - do not harbor such a diversity of knowledge, and hence have become more dependent on inter-organizational cooperation and the formation of complex networks.
4- a strong trend of privatization and commodification of knowledge has resulted
5- markets for knowledge develop further

6- this requires the codification of tacit knowledge, with the consequence that knowledge systems become less local, less space dependent

7- Though the privatization of knowledge creates needed incentives for their production, and facilitates trading, it entails also a number or risks or disadvantages: lengthy negotiations over licensing, ‘closure’ and segmentation of knowledge communities, an interest in exploitation of patents; and a reduction of the incentive of private actors to invest in basic research which does not have immediately visible commercial application. These all could in the long run retard or frustrate further innovation.

As to the *organizational architecture* of the idea-innovation chain:

8- A further differentiation of stages and tasks in the idea-innovation chain, including the differentiation of product idea-innovation chains in sub-chains for knowledge that is fed into them (as knowledge itself has become a commodity), e.g. in biotech for the development of research tools and platform technologies. Thus chains have become *webs of chains*.

9- These webs include many different organizations, specialized on a) various parts, products and services; b) stages in the chains (product development, system construction, end products, marketing, quality control, after sales service); and c) specific kinds of knowledge inputs.

10- Nevertheless, on the whole large firm hierarchies that already dominated the industries before the paradigm shifts still occupy a strong position, due to the huge capital investments needed for exploration and exploitation of knowledge.

11- But these major players do tend to outsource, with the consequence that a host of smaller ‘satellites’ around these major companies have developed

12- Making coordination and integration in the chain an ever more important imperative. Whereas in the past this was done through the allocation principles of ‘state’ (large state enterprises in telecom) and private ‘hierarchies’, now ‘markets’ and ‘networks’ have become more important. *Intra*-organizational relations are being replaced by *inter*-organizational ones, also between public and private organizations. A host of embryonic and hybrid organizational forms have developed to bridge such relations.

13- Within these networks of stable customer-supplier relations, spatial proximity, i.e. regional clustering, is an asset. Nevertheless, we also find that the division of labor within webs of idea-innovation chains covers large international distances, both within and between firms. What evolves are networks of regional clusters, each specializing on certain phases in the chain, with European regions focusing on product development, engineering, design, marketing and brand management, and less in manufacturing.

Apart from these common trends there were also differences in the way our countries reacted to the paradigm change.

In telecom the starting positions were on the one hand different - Germany and the Netherlands had with Siemens and Philips a relatively strong position in the industry - but in other respects similar. As regards organization, all had protected domestic markets, dominated by monopolistic hierarchies (with Finland being somewhat of an exception with a duopoly of service providers). How did they react to the windows of opportunity (WoO)?

- In Germany an already strong position in telecom was fortified. The starting condition of a large domestic market gave Siemens a head start. The country could, in a path dependent manner, take advantage of the WoO.
- The Netherlands and Austria did not profit from the WoO. Dutch Philips backed out, perhaps because it tried to early to occupy an international leading position, at a time when markets were still nationally segmented. Austria could not break the dominance of foreign suppliers and develop its own industry. Both countries managed however to occupy certain niches, the Netherlands in cables, and Austria in speech recognition and software adapting equipment to East European markets.

- The success story of exploiting the WoO is Finland. It managed to develop with Nokia a leading position in the world in telecom. Favorable conditions were: a) a sense of vulnerability fed by the dependence on paper and pulp industry and the loss of the Russian market; b) exploitation of some path dependent advantages: early duopoly in service, experience of (technical) competition, early importance of radio communications. In fact, disadvantages (the empty north, migration to the south) became advantages; c) institutional supports: a flexible education system, close relations between universities, research institutes and firms; and an active and concerted technology policy.

In biotech the starting positions of the countries before the paradigm change were more different. This was because biotech has been applied in various old industries where our countries had a differentially strong position.

Germany had a well developed pharmaceutical industry. It seems to be - though belatedly - successful in escaping from the 'chemical paradigm' that characterized the industry and is catching up in red biotech. Path dependency turned out to be of advantage. The same seemed to be the case for the Netherlands. This country is traditionally strong in the agro-food sector, and the infrastructure that was in place helped to exploit the possibilities of green biotech. However, this path dependent advantage turned into a disadvantage when green biotech become more controversial.

Austria and Finland both missed strong sectors on which biotech development could build. Attempts to do so nevertheless were least successful in Austria, where biotech development is hampered by a number of path dependent factors, such as a weak industrial tradition, less inter-firm and firm-university cooperation, a more defensive and traditional industrial policy instead of an active technology policy, and the absence of a sense of crisis which made it possible for Finland to engage in a concerted innovation policy. While the changes in Eastern Europe were a threat to Finland, they became an extra opportunity to Austria, given the strategic location of Vienna.

On the whole strong sectoral specialization in telecom and biotech before the paradigm change continued. Existing sectors managed to exploit windows of opportunity in their own sector: German telecom and pharmaceuticals, and Dutch agro-food and the telecom niche of cables. There are no cases where strong path dependency in the old paradigm hampered development. We found only one case of escape from path dependency in other sectors towards our two, the success of Finland in telecom.

To what extent did institutions provide constraints or opportunities for these changes?

- Finance does not seem to have been a major constraint in telecom. It has been so in biotech, especially for start-ups and especially in Austria
- Educational resources have been a bottleneck particularly in Germany. Finnish and Dutch firms have profited from more flexible higher educational institutions
- The concerted effort that the Finns put into public policy and education for biotechnology and telecommunications paid off. By contrast, the restrictions of finance and law on Austrian biotechnology plus a long-term lack of technology policy partly explain the relative poor Austrian performance. Legal restrictions hampered green biotech. A lack of finance and technology policy made Austria into a laggard as regards international technological developments. Dutch public policy put emphasis on developing and nurturing an entrepreneurial spirit, reinvigorating a tradition with a long history.
- In both sectors a decline in importance of national institutions can be noticed. Firms can recruit personnel from the US or elsewhere. Some pharmaceutical companies have people from 35 countries working for them. Telecommunications is even more global, and is dominated by big players. However, national institutions created path dependency.

These findings bring us to question the wisdom of some major policy measures of Member States as well as the EU:

- the on-going privatization of knowledge leads private business to retreat from the production of basic research. This trend is amplified rather than countered by a commercialization strategy followed by publicly funded research institutes, and instigated by politics. The end result could be a shortage of basic research and a threat to long-term innovativeness.

- Specialized organizations in the idea-innovation chain have to cooperate closer in networks, as innovation requires the combination of ever diverse competences. This could be hampered by strict competition policies. Making exceptions for pre-competitive research cooperation does not avoid this, as firms need to be able to cooperate in ‘exploitation’ of knowledge in order to be willing to cooperate in ‘exploration’ of knowledge.
- European firms increasingly specialize on phases in the beginning and end of the idea-innovation chain: research, product development, design, quality control, marketing, after sales services, while manufacturing is outsourced to companies outside of Europe. This puts into question whether two contradictory paradoxes, with which our project started - the Austrian paradox (low R&D investment, but good economic performance) and the European paradox ((high R&D investment, but not enough exploitation in manufacture) - are really policy ‘problems’. Should we really regret European specialization on knowledge production in a time when knowledge itself is becoming more and more of a tradable, and hence income generating, commodity?

Chapter 1. Introduction

Frans van Waarden

Countries differ in innovativeness, a statement that has become almost a commonplace. Porter (1991) has shown that commercial innovative activity is not spread evenly across nations. But countries differ also in other indicators of innovative output: number of patents registered, new products and processes developed, new firms founded in new promising sectors, successful marketing and commercialization, their trade balance in high tech products, etc. Some countries create frequently totally new products and new industries, while others rarely create either. Some make radical innovations but fail to successfully market them, while others make more incremental innovations, yet have more commercial success. Most product and process innovations are done in about 15 to 20 of all the 186 countries in the world. But even among these 20, there are significant differences in innovative performance.

Furthermore, countries differ not only in the degree of innovativeness, but also in its pattern and direction, in the sectors in which they are innovative. Quite a few have developed nationally specific technological trajectories and patterns of industrial specialization. Germany, for example, has continued to be enormously innovative in industries in which it was already competitive before World War II: paper, printing, materials, machinery, electro-technical products, motor vehicles, chemicals and textiles. However, it seems to have been less successful in newly emerging complex, knowledge-intensive industries such as electronics and aircraft manufacturing. The Americans, in contrast, have in more recent years made radical innovations in these and other industries which have short product life cycles and are based on rapidly changing and complex technologies. In doing so, they have also succeeded in creating totally new industries with significant economic impact.

Traditional explanations in the economics of innovation have tried to explain both differences in amount and in specialization pattern of innovation output by differences in *input*. Amounts of output were related to amounts of investment in R and D, capital investment in general, supply of qualified labor, etc. And original specialization patterns have been explained by the relative abundance of important input factors. An early and basic one was the availability of abundant and cheap raw materials: steel industry clusters on top of coal or iron ore deposits; pulp and paper industries in countries with endless forests. Another was the availability of cheap energy: the early metal working industry near the watermills at the edges of the German Bergisches Land. Infrastructure and location on trade routes were a third important input factor: for trade and trade-derived industries, as the bulk chemical industries in major harbors. The availability of cheap, semi-skilled and unemployed labor (originally especially in the winters) explained the development of the cotton industry in the East of the Netherlands and the fine mechanics (cuckoo clocks, later record players) in the German Black Forest. Finally, the presence of knowledge creating institutes fostered the development of knowledge-based industries. Thus David Landes (1969) has argued that Germany was so successful in the second industrial revolution because of the characteristics of its education and research systems which were lacking in Britain and elsewhere. This helped Germany to create new industries based on chemistry and physics.

However, mere input factors cannot explain the national differences found. For one, because even though expenditures and resources may have varied over time, the sectoral specializations of countries have been rather enduring over time.

A second argument why inputs cannot do the explanation is that there are even important cases of an inverse relation between R and D expenditures and successful commercial innovation and economic performance. The European ‘White Paper on Growth, Competitiveness, Employment’ (EU 1994) and the ‘Green Paper on Innovation’ (EU 1995) identified what has become known as the *European paradox*: Notwithstanding its relatively high expenditures on R and D, the European economy is characterized by an ‘insufficient capacity to innovate, to launch new products and services, to market them rapidly and, finally, to react rapidly to changes in demand’ (EU 1995: 7), or a ‘comparatively limited capacity to convert scientific breakthroughs and technological achievements into industrial and commercial success’ (EU 1994). The reverse is also found, and has been called the *Austrian paradox*, after the country that exhibits this combination of low R and D expenditures but nevertheless rather strong economic performance.

Abundance of specific inputs may explain the original creation of an industry in a certain place, but not its persistence over time, as frequently product and process innovations have made it less dependent in time on those resources, originally so important for its location.

Once a sectoral specialization or technological trajectory has been created, other factors work towards its persistence in time and space. We could summarize these as the ‘six I’s’:

1- institutes. Industrial development implies the creation of organizations, specifically for that industry: firms, research and educational institutes, standardization bodies, quality control agencies, financial institutes, trade associations, and other organizations. These have - as any organization - a tendency of self-perpetuation.

2- interdependencies and interlinkages. These institutes are interdependent and interlinked through one of more forms of economic governance: markets, hierarchies, networks, clans, associations, and public-private partnerships.

3- interests. The institutes have interests in survival and growth, e.g. through the continued investment of private and public funds in these industries and their - incremental - development.

4- ideas, information, knowledge, competencies. Specialization implies the accumulation of competencies, both in the form of tacit knowledge embodied/embedded in personnel; and in that of codified knowledge, expressed in patents, publications, archives, or training programs. This information, knowledge, and skills, developed in specialization, provide for a competitive advantage, at least as long as these competencies are still useful for innovation.

5- incentives. The investments in institutes and ideas motivate people (workers, entrepreneurs, and researchers) to invest further in what they already have, that is, along familiar lines, in order to exploit their competitive knowledge advantage to the utmost

6- institutions. The interests and incentives make the institutes create institutions - defined as social rule systems - that help perpetuate all the former items; e.g. by giving preferential treatment to established institutes, ideas, or interlinkages.

Such societal factors translate for economists in benefits (in particular: increasing returns to scale), but also in ‘costs’: the costs of choosing an alternative line of development: The cost of destroying existing competencies and institutions, the costs of fighting established interests who defend their turf, etc.

Together, these elements develop an ‘institutional history’ over time, which persists as long as some minimal economic and innovative performance is realized. The discovery in 19th century Germany that a wide array of pharmaceuticals and dyes could be developed from aniline sparked the development of an extensive chemical industry. This industrial infrastructure: large firms, know how, experience with specific product development, research laboratories, networks among different firms, reputation of quality and reliability among customers, trust among financiers that new innovations would succeed, industrial standards, quality norms and other regulatory protections - all these institutions gave the country a competitive advantage over other countries, also in the development of further innovations within this sector.

These elements form interdependent configurations, i.e. ‘systems of innovation’. Where the sectoral specializations are specific for a country, and the institutions nation-wide, the systems can be considered ‘national’. That would be one way of giving meaning to the term ‘national system of innovation’, which has recently produced a burgeoning literature, since the original work of Freeman (1987), Nelson (1987, 1988, 1993), Porter (1990) and Lundvall (1992). Its formal codification has been the acceptance by the OECD (1999). The common assumption in this literature is, that ‘nation matters’. But what does that mean? Basically that certain nationally specific characteristics favor specific industries and/or enhance specific path dependencies. And that these characteristics form some sort of ‘system’. As has however regularly been remarked (Meeus 1999), the concept has remained somewhat of a ‘black box’ with different meanings, varying from a set of supporting institutions (Nelson 1993) to ‘flows’ within networks of constituent organizations (OECD 1999).

The ‘systems of innovation’, that develop in specialization, make that a firm, region or country, which already excels in one product line, can become even better at it - until the system turns from being asset into liability, e.g. when it hinders further developments within or outside the existing product-lines.

Such can be the case after radical innovations or other major technological upheavals, that often make existing competencies obsolescent, and with it their institutes, interlinkages and institutions. However, such radical innovations may also form ‘windows of opportunity’ to escape from path dependencies. As formerly useful, and commercially exploitable, competencies become redundant, the organizations and institutions that find a reason for existence in their generation may loose their reason for existence, and their influence as economic and political interests. The need for new knowledge, new combinations of knowledge, may spurt the creation of new organizations and institutions. New firms may find opportunities to enter markets, and existing firms are forced to - but also get a chance - to reorganize or to engage in new linkages to rather different organizations.

In this study we have focused on two such radical innovations - we speak of technological paradigm changes - in telecommunications and biotechnology, i.e. in two science-based industries. In telecommunications we focused on the change from the electro-mechanical to the optical-digital technological paradigm; and in biotechnology on the change from classical ‘trial and error’ biotechnology to modern biotechnology based on genomics. Both took place in the last quarter century, with modern biotechnology being the more recent one. These are typical radical innovations that have mitigated if not destroyed the usefulness of existing competencies; and that may have provided ‘windows of opportunity’ to economies to escape from path dependencies.

The selection of countries to study these changes has been guided by the fact that most research on national systems of innovation has concerned larger countries, such as Japan, the U.S., and Britain. The smaller European countries have not been analyzed in a systematic way, with the exception of Sweden. This neglect of the smaller European countries is deplorable, since some of these countries have a long-term (and innovative) presence in technologically advanced industries. Furthermore, these smaller economies have been relatively open to international trade, are used to being exposed to foreign competition, and have, on the whole, performed rather well in this competitive struggle

Therefore, we have selected three smaller European countries for our study: Austria, Finland, and the Netherlands, and have included Germany as a contrasting larger country. Although they have common characteristics in some areas, they differ in others, making comparison worthwhile.

First of all, they differ in the importance of the industries selected. Germany and the Netherlands both have long-standing electronics/ICT sectors and agro and pharma-industries (where biotech has made most inroads). Finland has become strong in telecommunications with a globally competing domestic firm (Nokia). Austria has no globally competing domestic firm, has low levels of R&D but, nevertheless, economic success.

The four countries also differ in the dominant institutional modes of economic governance. In the Finnish and Dutch economies, coordination through the organizational hierarchies of large multinational enterprises is relatively important, whereas they play almost no role in Austria. In Austria and the Netherlands associations and corporatist institutions that mediate state-industry relations are very important. Germany usually is classified as having a „company led" model of growth and innovation (Zysman 1983), although coordination through associations and the state are also of some importance. In Finland, "fair weather corporatism" works in good times but not in bad times. These four countries differ on the institutional variables relevant for the governance of idea-innovation chains: in their educational and vocational training systems, their capital markets, and the organization of their states (federal or unitary).

Finally, the four countries differ in the strength of different parts of the idea-innovation chain. By the latter we understand the fact that an innovation process undergoes different phases until an idea becomes a marketable product. The *idea innovation chain* consists of -loosely or tightly connected- networks involved in the various stages of the innovation process: basic research, applied research, product development, production, quality control, marketing and sales. This concept does not necessarily imply a linear relationship between the various components of the chain. Innovation is a process of moving back and forth between invention and/or design, development and testing, redesign and evaluation of market potential (Kline/Rosenberg, 1986). From basic research to applied research, manufacturing, marketing and sales is a long way. Only the big country Germany is strong in all links of the chain, the other countries have some weak parts and the importance and performance of these parts also changed with the paradigm shift.

The leading research questions in this project are hence:

1- What changes have taken place in the 'systems of governance of innovation' in telecom and biotechnology in our countries in the wake of the technological paradigm shifts ? Have our countries hit upon the 'windows of opportunity' they provided, and if so how? Have the different countries reacted differently, or with different speeds, to these technological changes? Have they found specific niches, not only in terms of products and markets, but also in the specific combination of institutions? How does each country differ from the 'general' pattern of change in these sectors?

More precisely:

2- How have the changes affected the *performance*? How well have our countries performed in these industries, relatively speaking, during and after the paradigm changes?

3- What have been the consequences for the *Organizational Architecture* of the Idea-Innovation Chain? E.g. new actors, changes in the structure and organization of the idea-innovation chain, new forms of interdependence, coordination and governance, changes in the flows of information?

4- To what extent have the national *institutions* that provide basic resources - knowledge, skills, and finance - hindered or facilitated such organizational changes? And have the resource-providing institutions themselves changed in response to changes in demand from the industries?

The project has used a variety of methods to collect and analyze data. In the analysis of the performance of national and sectoral systems of innovation, data on quantitative indicators has been drawn from the extensive literature and available statistical sources (national research statistics, patent statistics, company reports). To study the organizational and institutional changes in the wake of the paradigm changes we have relied more on sources of qualitative information: documents, visits to the relevant organizations and interviews with key persons. Altogether, we have had more than 150 expert interviews with representatives of firms involved, trade and business associations, research organizations, universities, public support institutes, bridging organizations, etc. in the four countries.

This version of the report summarizes the findings of the study. Chapter 2 describes the technological paradigm changes that took place in telecommunications and biotechnology. Chapter 3 shows the changing needs for knowledge resulting from the paradigm shifts. Chapter 4 compares the innovative and economic performance of our countries and sectors, and provides a starting point, a riddle to be solved, in the country-sector studies. As organizational changes that took place in the wake of the technological paradigm shifts we identified changes in the architecture of the idea-innovation chain (Chapter 5) and regional clustering (Chapter 6). Chapter 7 discusses and compares subsequently the institutions where firms in our sectors can and do get their input factors: finance and skilled personnel. Chapter 8 discusses the regulatory and (technology) policy framework, both as provided by the states in the different countries, and by private organizations themselves, notably the increased importance and change in the manner of creating technical standards. Chapter 9 shows the importance of path dependencies in industrial and innovative development. It gives answers to the question, to what extent idea-innovation chains are still national, and hence, whether 'national systems of innovation' still matter. It also contains some policy recommendations.

Part II of the report, called Annex I, published separately, consists of eight country-sector studies, of the two sectors in our two countries. They are summaries of longer (100-150 page) studies which have been written earlier on in the project and which are available as working documents. They describe and analyze the changes that took place in the organization of the idea-innovation chain in the wake of the paradigm changes in the respective sectors and countries. The sector studies pay successively attention to the performance of the sector before and after the changes, the changes in organizational structure, and they describe relevant aspects of the institutional environment that either facilitated or frustrated changes. In addition, each of the sector studies has a red threat or riddle that it tries to solve, and that usually departs from the relative performance of the sector: how and why was the Finnish telecom industry able to escape from path dependency and foreign domination, and succeeded in transforming a domestic firm, formerly specialized in forestry, into the world leader in mobile telecommunications? But: why did not Dutch not succeed in becoming a global player in telecom, starting from the base of their electronics multinational Philips? Or: when and why was the German biotech industry able to catch up with international developments? Or: is the Austrian paradigm - low innovation, good economic performance - in the long run tenable at the sector level?

Chapter 2. Technological Paradigm Shifts in Telecom and Biotech

Herman Oosterwijk

The fact that telecommunications and biotechnology have undergone major changes in technology, makes them especially interesting for our research; in particular, how changes of the technological paradigm have influenced the flow of knowledge, needed to bring advanced products and services to the market. In this chapter we will first define science based industries and then discuss the major technological changes that have taken place in the two sectors.

2.1. Science Based Industries

Diffusion of academic technology transfer to industry has been increasingly important for a country's economic development. It was especially after World War II that science and industry strengthened their mutual relations, not only in the US, but also in the European countries. High-tech industries developed, building on close relations between academia and industry. The term 'high-tech' was especially used as the denominator for the emerging electronics industry, but with the emergence of similar dense relations in other scientific fields the term 'science-based industries' was used introduced. The distinguishing feature of firms in science-based industries is that a significant part of their knowledge base lies not inside the firm itself and other firms, but in universities and public research institutes (Fransman, 2001, p. 264).

Pavitt (1984) was among the first to be more precise about what exactly should be categorised as science based sectors, thus reaching further than a sense of common understanding. He examined firm-structures in several industrial sectors and traced the flows of products and knowledge within and between sectors. In his analysis science-based firms are to be found in electronics, organic chemistry (partly), pharmaceuticals and biotechnology, aerospace, and military technology. Grupp and Schmoch (1992a,b) have built on the work of Narin and Noma (1985), who suggested to take the citation of scientific articles in official search reports of patents as an indicator[1]. Thus it is possible to operationalise the notion of science based technologies in a quantitative way; science based technologies are defined as fields with frequent reference to scientific publications (Meyer-Kramer and Schmoch, 1998, p. 836).

Grupp and Schmoch have transferred this approach, which was originally developed for the US Patent and Trademark Office, to patent applications at the European Patent Office and applied it to the analysis patents in 30 major technological fields between 1989 and 1992 (Grupp and Schmoch, 1995). According to their analysis, biotechnology has the highest science linkage (81), followed by pharmaceuticals (66) and semiconductors (61). Most other fields with indices above the average are related to chemistry and the broad field of information technology, whereas sectors with indices less than average are to be found in the process industry, instruments, mechanical engineering and consumer goods.

[1] Usually patent office examiners refer to other patents, because descriptions found in patents are more precise than in scientific articles, but if they cannot find relevant patents, they also refer to scientific articles.

2.2. Change of Technological Paradigm

In this project we have confined ourselves to two sectors with a science-base clearly above the average: *telecommunication* and *biotechnology*. The telecommunication industry is a relatively old industry, stable until the 1980s, but with considerable changes ever since. The introduction of digital technology in the mid 1980s has generated a multitude of developments in technology, products and services, as well as it has fuelled changes in the regulatory and institutional environment. The impact of the introduction of digital equipment, which was indeed a radical innovation, could only be fully exploited, because it was followed by a second revolution: the introduction of high-capacity optical transmission equipment. The combination of digital and optical equipment has boosted both quality and capacity of the telecommunication system. It provided not only the technological infrastructure to more customers, it also provided more services at cheaper prices. The change from the electro-mechanical to the digital-optical paradigm has provided the right conditions for a tremendous increase in data-transmission and a third revolution is about to take place: the change from a hierarchical architecture of the telephone-network towards the matrix-like architecture based on Internet-protocols. For telecommunication we have focussed our research efforts on innovation processes in the heart of the system: telecommunication *hardware*, especially *switchboards* and *transmission* equipment.

The principles of biotechnology have been grounded in ancient times and the term biotechnology was only used in the 1920s for the first time, but we have focussed our research efforts on the developments since the 1980s, when modern biotechnology came to blossom. The distinguishing feature which discriminates *modern* biotechnology from *classical* biotechnology is that it goes beyond the (natural) limitations of (certain families of) species in its attempts to integrate natural sciences and engineering to find novel combinations of organisms and cells, which can be used in novel products and services. Modern biotechnology is using and combining the genes of unrelated species, whereas classical biotechnology has to confine itself to related species.

In telecommunication we can observe that a basic analogue technology has flared out in a range of new applications in structure as well as in services. In modern biotechnology we find basic principles, but as soon as new technologies have been introduced, a range of radical innovations take place in several a range of areas: healthcare, agriculture, food-production, environmental care, fine chemicals, etc. It almost seems as if the tools of the bio-technological toolbox rewrite the basic principles in many fields of applications. That is what makes these sectors so interesting for our research. They have been selected as they provide variation in national institutional arrangements and institutional variation between the two sectors.

2.3. The Technological Development in the Telecommunication Sector

Telephony stood long time in the shadow of the telegraph. Compared to the telephone system, the telegraph system was a very robust system, reliable to the utmost and easy to repair, if necessary, even with iron wire and adhesive tape. Yet, the term *telecommunication* was almost exclusively used as a synonym for *telephony* until the 1980s.

The telephone was first applied in hotels to bridge the distance between rooms, reception, kitchen and stable, basically as a means of convenience. Later, private companies introduced the telephone into the public sphere, initially setting up networks in local -preferably densely populated- communities, because the telephone signal was very susceptible to fading and noise as distance between sender and receiver increased. The first cross-border telephone line between

Vienna and Berlin faced the so far only nationally oriented network-operators with the new problem of network-compatibility. The initiatives taken by several countries at that time to discuss the problems of inter-connectivity have ultimately lead to the foundation of the International Telecommunication Union (ITU), until the 1980s the most dominant international institute for standardisation of telecommunication systems.

Communication between countries was the most complicated aspect, because inter-connectivity of systems demanded international consultation and technological adjustment. The gradual extension of the system at the turn of the last century has provided the hierarchical structure for the telephone system as we still know it today. In fact, until the introduction of the digital system in the 1980s, the system has been upgraded time and time again, yet, leaving its major architecture and characteristics largely unaffected. Switchboards were initially manually operated, usually by woman-operators, who established connections between individual subscribers by connecting plugs on the switchboard. As a result of an increasing automation of switchboard technology, the mediation of an operator was no longer required in the local network, but the mediation of an operator was still needed for long-distance, international and mobile calls. Switchboard technology has been a constant attempt to gradually increase speed and capacity of equipment. The first simple systems, which used brass levers was gradually replaced by faster moving elements and -as of the 1970s- by relays, which increased speed as well as capacity. Until that time the telecommunication system was a perfect stable system and it was no exception when switching elements were used for several decades. The switching elements were highly sophisticated pieces of machinery, with a tremendous life-span. The only reason to replace elements of the system was not so much malfunction or wear, but increasing demand for telephone services, and thus capacity. Increasing demand had also implications for the transmission media, especially regarding the connections between the switching nodes. The simple airlines, which have dominated the landscape for so many years, had insufficient capacity and were gradually replaced by high-capacity ground-cables. Some countries have experimented with coaxial cables, which combined high capacity with a much lower weight than the commonly used twisted-pair cables. Connection between switching nodes were also established through radio-beam links and -still later- satellites.

The first real change, which was the prelude to digitalisation of switching equipment, was the introduction in the mid 1970s of Stored Programme Control (SPC) switchboard. In fact this was a classical, albeit modernised electromechanical switchboard, yet, with a computer attached. This opened the door to a further extension of services such as.wake-up calls. The most spectacular changes have, however, taken place in data-transmission. In the early 1980s the business sector could subscribe to packet-switched networks and as of 1985, they could communicate worldwide. Based on this technology new serviced were developed like for instance Teletext, which was a much faster and more flexible service than its predecessor the Telex.

2.3.1. Change of Paradigm I: from Analogue to Digital

An event with far-reaching implications was the introduction of digital equipment in the early 1980s. Whereas the old analogue system was based on a electrical (galvanic) connection between two subscribers, in digital equipment this connection was made by soft-ware. The hardware was basically a state-of-the-art, high-powered computer. To explain the difference between these two systems, and especially the limitation of analogue systems, we have to make a little technical sidestep.

Analogue systems basically transmit the sound of the human voice just as it is recorded in the microphone. Sound-waves are translated in corresponding electrical waves. If one would attach the voice-signal to an oscillator one would see a regular wave, moving with every spoken word. However, in a moment of silence, one would still see waves, albeit very small. These are not caused by *voice*, but by *noise*. Analogue lines are susceptible to noise, static interference and fading with distance. A common way to deal with this problem is to amplify the signal during transmission and this has been done for many years, yet, without solving the problem. Not only the voice-signal is amplified, but also the noise.

Digital systems do not have the same disadvantages as analogue systems. They transmit signals in binary bits, which have just two positions: *on* or *off*. In digital technology it is much easier to filter out noise, because an amplifier -a digital regenerator- can discriminate between signal and noise. As a result digital signals have a higher speed, have a much better voice quality, fewer errors and the peripheral equipment is less complex.

No wonder that most telecommunication operators changed to digital equipment in the course of the 1980s. The quality of digital signals has provided the platform for a range of new services, especially in data-communication. The advantages for private subscribers, apart from some new services, however, were not so obvious. Only the dial, which had dominated the telephone for so many years was replaced by push-buttons.

2.3.2. Change of Paradigm II: Change of Network Architecture

Voice-signals have been transmitted in the network through a hierarchical system of circuit switching. For each telephone-call an exclusive galvanic connection is made between the individual subscribers for the duration of the call. After the call the circuit is given free for other calls. Although it is a good system from the customer's perspective, it is an inefficient system for the network-operator. The one who is speaking is sending a signals, but the receiver is listening, not sending a signal at all, thus using the system for only half its capacity. Especially in data-transmission this is regarded a waste of energy.

Digitalisation has provided the platform for high quality and high speed data-transmission and the success of these services was such that demand for data-communication increased. This has put pressure on the operators to increase network-capacity. But another development took place. Data-transmission has been a bridge between the world of telecommunication and computers. Especially the success of the Internet in the 1990 has really boosted demand for capacity. What the telecommunication system needed was a true work-horse, that could transport huge amounts of signals, voice as well as data. Especially the lines between switching nodes in the telephone network and in the data-network had to transmit solid amounts of signals. The operators had several options, radio-beam, twisted cables or coax cable. Optical cables was another alternative, but the costs of introduction were considered too high.

2.3.3. Change of Paradigm III: from Electrical to Optical Transmission

The old electrical systems were susceptible to fading and the only way to solve that problem was to build amplifiers on regular intervals. These amplifiers had to be powered, which consumed electricity and their functioning was checked every month by a mechanic. There were at least 20 amplification points on a thirty kilometre line and it took at least between six and eight work-hours a month to check the amplifiers, let alone to repair them. Constructing a network was not easy: the cables were thick and heavy. The cables were renewed every seven to ten years. No wonder that Dutch PTT would only consider the use of optical fibres if they could bridge a distance of thirty kilometres without amplification. Operators in other countries had similar requests and as of 1985 optical cables were used in the (trunk) network. An optical fibre is build up of a *core* and a *cladding*. The core has a higher refractive index than the cladding. Light-rays are completely reflected when they strike the core/cladding interface and thus propagated through the network. Optical fibres used in telecommunications are made from glass-fibres, each being thin as a human hair, The advantages of optical fibres compared to copper cables are: fewer losses; larger bandwidth; reduced bending radius of cables; unaffected by electromagnetic interference, not producing interference; more difficult to tap illegally; and a great potential for increasing capacity in the future, without replacing the medium. But next to these technical advantages, it has the advantage of much lower operation and virtually no maintenance costs. But the real big advantage is its extremely high capacity. A glass-fibre network has ‘broadband’ characteristics, allowing for the transmission of TV and video signals, while the ‘old’ telephone network has ‘narrowband’ characteristics. Optical fibre is thus the workhorse, especially suited for data communication.

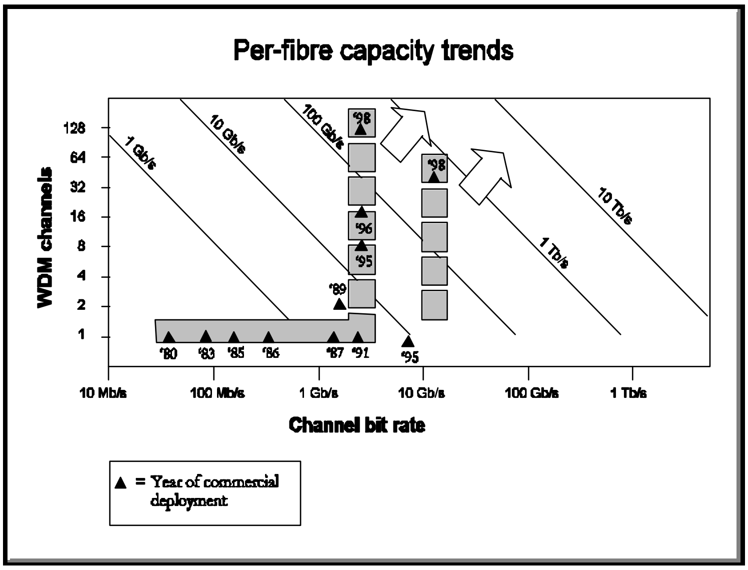


Figure 2.1. Individual fibre capacity

Source: Bell-Labs - Lucent in EITO2000/Bozetti

The mid 1980s has been the watershed between the analogue, electro-mechanical paradigm and the digital-optical paradigm. This went parallel with privatization of the former national operators and liberalization of the market, usually starting with end-user equipment, but gradually opening the market in all aspects of telecommunication. The introduction of mobile telecommunication in the mid-1990 (in some countries even earlier) is the most visible aspect of the changes that have been brought about. Technology based on Internet protocol is under construction and it is expected that voice-communication will soon be part of that development. As a combined result of all these changes, the landscape in telecommunication research has undergone drastic change. In the 1980s the classical analogue switchboard, which used to be the domain of telecommunication engineers was replaced by the digital switch-board. As a result the emphasis in research changed in the 1980s from hardware to software, leaving hardware basically the domain of computer-engineers and software the domain of Information and Communication Technology. Technical research thus changed to service oriented research and man-machine interaction. The development of new services and service platforms has become the main theme in telecommunication research and, although the next step from circuit switched to packet switched technology will be a major step, it is unlikely to change the situation in research as much as the digital/optical revolution.

2.4. Biotechnology

Biotechnology has been in the centre of the public debate since the 1990s. Most of the public’s attention was driven to the application of biotechnology in food, animals and agricultural production. The fierceness of the debate, under the heading *'Frankenstein food'* easily lead to the impression that biotechnology was a novel technology, *'invented'* at the end of the twentieth century. But the ancient Egyptians were already familiar with the use of yeast to make bread prove. People have used biological knowledge for ages in the production of wine and beer, as they have also tried to improve the quality of their life stock and crops, by combining the traits of promising species. As a result of these processes farmers managed for instance to grow the sugar-beet as we know it today, from a tine root that originally grew in the dunes. A good eye for the right combination was the necessary asset for a farmer who wanted to improve quality of life stock and crops. 'Biotechnology' was used for the first time at the beginning of the twentieth century to give this common knowledge a scientific label. Biotechnology was, next to its applications in agriculture and food-production, also extended to drug production. Penicillin, for example, was a rather unintended side effect of Fleming's research on influenza and the outcome of trial and error and sheer luck. A leap forwards was the discovery of the DNA-structure in 1953 by Crick and Watson. Their work helped to understand the hereditary properties of species, whether in small organisms, like in yeast, bacteria, en enzymes, as in larger and more complex organisms. Knowledge of the gene-structure had the promise of new approaches in biotechnology. Instead of the trial and error approach in traditional biotechnology with its uncertain outcomes, this knowledge provided the basic ingredients to target specific and well defined outcomes.

Nowadays one makes the distinction between *classical* and *modern* biotechnology, but both approaches stem from the same definition: *'The integration of natural science and engineering in order to achieve the application of organisms, cells, parts thereof and molecular analogs for products and services.'* (European Federation of Biotechnology, 1989)

Classical biotechnology as well as modern biotechnology have basically used the same science-base; the knowledge and the application of genes. However, whereas classical biotechnology had to restricts itself to the traits that were inherent to the species or related species, and tries to enhance certain qualities by breeding and cross breeding technologies; modern biotechnology does not restrict itself to one family of species; it rather tries to find novel combinations, also using genes from not related species. Genes of an onion are used to improve saccharine production in sugar-beets. Genes of flowers are used in golden rice with increased yield of carotene. That is why the term 'genetic engineering' is often used as an equivalent for modern biotechnology. Modern biotechnology is the epitome for techniques like DNA analysis, cell-fusion, bio-catalysis, bio-informatics, organ- and tissue-cultures, etc. The term, 'biotechnology' thus refers to a toolbox of techniques, applied in a range of fields, such as healthcare, diagnostics, agriculture (crop and cattle-breeding), foods, drinks, fine chemicals and environmental care. This summation is not exhaustive; the toolbox is constantly filled with new tools. Molecular biology, for instance, is such a new technique, with a variety of new applications. It ranges from 'cloning', which is basically *'making more of the same'*, to techniques to insert genetical information from one organism into another (not related) organism. These techniques are hidden behind concepts like: genetical modification and manipulation, genetical engineering, and recombinant DNA .

Knowing the DNA structure is one step, but understanding the genetic information is another. Celera Genomics and the Human Genome Project have both set up projects to unravel the genetic structure of the human DNA, initially as rivalling groups, but in the end in close collaboration, involving research groups from many different countries. The project was successfully ended early 2001 and has been a true revolution. Having all the information allows for entrance in the relations between hereditary patterns and specific diseases, and thus to a new approach in health-care. The interaction between the DNA structure and cells is of the utmost importance in modern healthcare. Research in this field of genomics mainly concentrates on the circumstances that trigger or activate gene-expression, on the differences that are brought forward by external influences like nutrition of the cell, on the influence of drugs and other chemicals, and even on psychological influences.

Expectations are high, especially in health care. The classical treatment of diseases, with broad spectrum chemical drugs, will be replaced by tailor made , personalised drugs, that repair certain defects in the hereditary structure of humans. It is generally foreseen that the impact of this new approach in treatment of diseases will be much stronger than the introduction of antibiotics in the 1940s.

2.4.1. 'Red' Biotechnology (in health care)

The application of modern biotechnology in health care are basically concentrated around two major themes: *drug-development* and *diagnostics.* For the effective treatment of diseases with drugs in the human body one has to identify *targets like* receptors, hormones, enzymes or growth factors, that correspond with a specific disease. Genetic research is especially used in the early phases of drug-development to detect targets which are related to a specific disease. If the relation between a certain protein and a disease is known, one can look for compounds that activate the body to make this protein, or in case the protein is produced in too large quantities, to stop the making of that specific protein. Bio-informatics will provide the databases and knowledge to analyse gene expression, genetic defects and gene-mutations, which are known to be the cause of that specific disease. It makes it much easier to access and analyse huge quantities of data and will help to bring down costs in drug development. It is expected that healthcare will gradually move from cure to prevention, customising medicine to individual needs.

Whereas drug-development is basically used in treatment and prevention, diagnostics are used to understand a specific gene expression, which makes a diagnose much more reliable in the detection of a specific disease or condition. Knowledge of the gene expression will also give information on the treatment of a specific patient, and helps to fine-tune the medication to the needs of a specific patient. Van Ommen et al. (1999) listed the following applications of DNA diagnostics in health research:

- *Monogenetic hereditary diseases*, which entails the dysfunction of one particular gene, which will lead to a specific disease. As the gene defects which are related to a specific disease are known, one can start large scale screening programmes, which is known as pre-symptomatic diagnosis.
- *Genetic risk in multi-factor diseases.* Cancer, heart and blood vessel diseases are caused by an interaction between hereditary factors and external factors, like smoking, nutrition, exercise, life style, etc. The interaction makes a diagnosis much more complex.
- *DNA diagnosis for medication.* With the monitoring of a patient's genetic constitution one can observe the influence of treatment by studying the gene expression. The analysis of gene expression of tumours can for instance contribute to new treatment of cancers.
- *DNA diagnosis at somatic mutation*, which entails the increase of knowledge in the course of a disease, such as for instance in cancer, caused by radiation.

Some applications of biotechnology in human healthcare are most promising, but still in an experimental stage. *Gene therapy,* aiming at the treatment of chronic diseases, is based on the natural ability of the body to bring genes to expression, which will strengthen or replace the function of a dysfunctional gene. Another option for the treatment of diseases or injuries is *Cloning* of specific tissue, because the human immune system will easily accept these new cells. The main technology is the transplant of a cell nucleus in a germ cell from which the nucleus was removed, which is the beginning of the development of new cell structures. *Xeno-transplant* is the use of tissue or organisms from animal origin in humans, to replace defect organisms in the human body. *Tissue engineering* is the cultivation of organisms or parts thereof in a medium, outside the body. This technology again has the advantage that the immune system does not reject this new bred tissue as foreign. The use of *transgene animals* in health research gives much insight in the development of diseases. Especially for this purpose transgene laboratory animals are bred, in which specific genes are eliminated. The use of *plants, animals and cell cultures in the production of drugs* is increasingly important.

2.4.2. 'Green' Biotechnology (agriculture and food production)

Genetical modification of plants has started in the 1980s, and were an attempt to make plants resistant to herbicides, pesticides and fungicides. A substantial acreage in the US, Canada and South America has already been planted with genetically modified crops, especially soybean, maize, cotton, rape (colza), tomatoes, potatoes and tobacco. Europe is in the process of field trials, and allows under strict conditions experiments in (sugar-) beet, lattice, cucumber, apples, strawberries, carrots, aubergines and several species of cabbage. Usually a division is made into two 'generations' of genetical modification. The first generation has mainly concentrated on the producers of crops and the efforts were aimed at increasing yield and decreasing the use of herbicides, pesticides and fungicides. The second generation aims at improving the plant, seen from the perspective of customers or environmental care. 'Golden rice' is an excellent example of such a crop. Its increased yield of carotene helps to prevent from blindness, which can be of major importance, especially in underdeveloped countries. Golden rice thus belongs to the 'green' sector as well as to the 'red'sector.

Next to multiplication and modification, biotechnology is also used as a genetic marker. This allows breeders to observe properties of a plant before it has reached the full-growth stage. Marker assisted breeding is especially important, because it can bring down development time with several years, especially for slow growing crops. Plant research is also very important in current genomics research. The unravelling of the gene structure of the sand-rocket (Arabidopsis thalianna) and rice will provide a better understanding of life processes in plants and the interaction between plants and their natural environment, which will be of great importance in food-production as well as in health care.

A common breeding technique for life-stock in agriculture is artificial insemination. Next to that technology new forms have been developed like *in vitro fertilisation* and *in vitro nursery* of embryos. These techniques are used to improve the efficiency of the selection process; to use species with specific genotypes; for monitoring the genetic structure of populations; and for the extension of gene migration in unrelated species. A second set of breeding techniques is cloning by a variety of techniques. A most interesting development in the breeding of animals is to alter the genetic structure. An interesting example in the Netherlands is to be found in the bull Herman, which was bred in the early 1990s by the Pharming group as a genetically modified animal. Its offspring has is different gene structure, which makes its milk easier digestible for humans with a specific intestinal disorder. However, most research on transgene animals is aimed at the breeding of laboratory animals to be used in medical experiments.

Transgene breeding techniques are not used in cattle for food production. Classical breeding technology still offers sufficient room for development and genetic uniformity is not very desirable in life-stock breeding.

A specific branch in biotechnology is the unravelling of the genomic structure of life stock. International consortia have set up programmes such as PigMaP for pigs, BoVMaPE for cattle, ChiCKMaP for chickens and other programmes for sheep, horses, turkeys, cats and deer. High potential genes can be identified, which is most valuable information for breeders.

In food we find several developments. First there is the development of novel foods. There are two directions in novel foods: *functional foods* or *nutriceuticals* and foods which have new characteristics through genetical modification (see the example of golden rice). Nutriceuticals are foods which have an extra active component. They are highly nutritive or have a clear health effect for specific groups. Again an example of products that are related to ‘green’ as well as ‘red’ biotechnology.

Biotechnology has also a wide-spread reach in production processes. In the context of food safety programs one aims at monitoring all the steps in the food-production chain. Here biotechnology offers a wide range of diagnostic kits to monitor food quality, hygiene or contamination. These diagnostic kits replace the classical and physical techniques of analyses.

2.4.3. ‘Grey’ Biotechnology (fine chemicals and environmental care)

The use of enzymes in the chemical industry is increasingly important, because it leads to biologically easier de-gradable products, and it is also easier in production. An example is the production of 6-amino penicillanic acid, which used to be produced in three steps under rather extreme circumstances. By the use of enzymes this process is now a one-step process under much milder circumstances, which puts less pressure on the environment and energy consumption. In this sense the use of enzymes in fine chemicals will lead to lower costs, which makes this technology extra attractive.

Biotechnology offers technology to prevent environmental pressure, it helps to detect pollution and it can be used as a cleansing of polluted air, water, soil and solid waste. In cleaning technology, biotechnology is used to break down nitrate, phosphate, metals, chlorinated hydrocarbons and certain toxic substances or to concentrate these substances after they have spread in the natural environment. Engineered micro-organism are especially suited for these purposed. They work faster, more precise and safer than their chemical counterparts. In general, these micro-organisms and bacteria are engineered in a classical way, rather than by genetic modification. A new perspective is offered by the use of genetical modified plants for bio-remediation. Immuno assays, basically monoclonal and poly-clonal antibodies are developed to measure specific kinds of contamination and pollution.

Chapter 3. Changing needs for knowledge

Herman Oosterwijk

3.1. Telecommunications

Research in telecommunication has undergone considerable change, especially since the introduction of digital technology in the network. The traditional suppliers of telecommunication equipment were usually closely tied to the national operators. Market-relations were dominated by these national operators, usually holding a monopoly for the provision of services. Finland used to be an exception in the sense that long-distance services were under the monopoly of the national operator, while regional services were under the monopoly of regional service providers. Thus, a certain degree of competition was apparent in Finland, but in general, market relations between operator and suppliers were as tight as in the other countries under review. In fact, market-relations were such that telecommunication equipment suppliers could easily lean back and wait for the annual telephone call of the national operator and jot down the order. However, the introduction of digital equipment in the 1980s has considerably changed the landscape in the telecommunication industry. Access to digital technology was a crucial condition to compete in the European market.

1980	1985	1990
Alcatel Thomson ITT Telettra	Alcatel ITT Telletra	Alcatel
AT&T APT (Philips) GTE Amper	AT&T GTE Amper	AT&T
Siemens Rolm Nixdorf GEC Plessey Stromberg/ Carlson GTE	Siemens Rolm (IBM) Nixdorf GEC Plessey GTE	Siemens
NEC	NEC	NEC
Nortel STC	Nortel STC	Nortel
Motorola	Motorola	Motorola
Ericsson Thorn MET (Matra)	Ericsson Thorn MET (Matra)	Ericsson
Fujitsu	Fujitsu	Fujitsu
Bosch Telenorma ANT Jemon- Schneider	Bosch Jeumon- Schneider	Bosch
IBM	IBM	IBM
27 companies	**22 companies**	**10 companies**

Table 3.1. Source: Roobeek, 1993, derived from SMAU Observatory On Information Technology, 1991

Especially the smaller European firms have had considerable trouble in getting access to new technology and had to choose whether to rely on their own knowledge development, or to merge with bigger or cash-rich companies, or to get access to licences and draw back on production. At that time it was expected that the market for telecommunication equipment was liable to the laws of ever increasing development costs and ever shortening product-life cycles. The expected short time to earn back development-cost demanded a substantial European market-share. However, the prospects to increase market-share were unfavourable, given the monopolistic nature of European telecommunications, and a wave of mergers and take-overs has overrun the European telecommunication market in the 1980s. Especially the telecommunication companies with market-shares below 9% in public switching equipment and limited market-share in foreign countries were absorbed by cash-rich companies.

The tendency during the latter half of the 1980s in the bigger European countries (Germany, France, UK, Italy and Spain) was towards a duopolistic market structure regarding switching equipment. Some smaller European countries also opted for a duopoly (Ireland, Norway, Denmark and Greece), but others opted for three or four suppliers (Belgium, Switzerland, Austria, Finland and the Netherlands). Still, market-shares within countries used to be rather stable. The change of technological paradigm has thus resulted in a further strengthening of already strong suppliers.

	AT	FI	DE	NL
Alcatel *	25	50	35	10**
Nortel	50			
Ericsson		35		30
Siemens	25	15	65	
APT (AT&T/Philips)				70

* Alcatel is the result of the venture of ITT and CGE
** Alcatel will have a 10% market share from 1989 on

Table 3.2. The public telephone market in Austria, Finland, Germany and the Netherlands: market-shares of main vendors in %
Source: Roobeek, 1988/ Computer Weekly 1986

The major change in research has been that the emphasis in research has changed from hardware to software, but the structure of the idea-innovation chain did not change so much. Research was set up as a sequential process, with ideas, gradually moving from one stage of development onto another. The basic outline for the organisation of the idea-innovation chain in the big telecommunication companies was a linear process, with hardly any feed-back-loops. Research usually started with applied research. Only the real giants in telecommunication equipment like AT&T with its Bell Labs, and to a lesser extent Alcatel, Ericsson and Siemens were able to hold a position in basic research. The principles of digital switching and digital transmission were known and success depended mostly on the extent to which firms were able to get a tight grip on software-development.

The first changes in the organisation of the idea-innovation chain emerged, when it became clear that the strength of telecommunication equipment was not so much in the hardware and components, but in software and services. The ability to write the right software, to design the right features, and to manage the system as a whole was more important than designing the right components. The tendency in the telecommunication industry is to out-source the design of technical components to specialised suppliers and to concentrate on software-development. Here we see that the telecommunication industry gradually is becoming susceptible to the dynamics and profile of the computer industry, or te make it even more general, to the electronics industry: ever fewer components, integration of functions and a range of specialised services, preferably combined in one piece of equipment. The mobile telephone is an excellent example. State of the art equipment combines voice and data-transmission, gives access to the Internet, it can be used as a play-station for music, video and games, its has organiser and word processing facilities, it is a camera, and what else can we think of. Research in telecommunication is no longer the exclusive field of telecommunication engineers, but is increasingly and extending its reach, building on generic technologies. The roots of development rather stem from electronics, computer and information science than from telecommunication as a specific line of development. Telecommunication is getting more and more intertwined with generic technologies.

The close knit between suppliers and operators has become obsolete in recent years. The basis under the principle of *Einheitstechnik*, as it was to be found in Germany and Austria, has lost its relevance; country specific standards are increasingly replaced by general industry-standards or international and pan-European standards. The national operators, of which some had substantial research capacities (especially in the Netherlands), have all withdrawn from technical research and if they still have research capacity it is oriented to services. The gravity of technical research is in the big telecommunication companies.

The field of telecommunication research has been a more or less ‘sheltered environment’ with strong mutual convictions, beliefs and codes. Telecommunication technology had an obsession with ‘foolproofness’. The quality of a system was largely measured by its failure rate and the design of switchboards has been as complicated as a modern aircraft, loaded with safety facilities and backup systems. Telecommunication engineers have put pride in fail-proof design and they have looked down for long time on computer-engineers, who have accepted a certain failure rate as a given thing. Thus, from that perspective, telecommunication used to be a field with its own dynamics, its own rules and its own convictions, and it was rather inside, technology oriented. Technology was thought to provide the right solutions and a certain conservatism was inherent to telecommunication research. However, the explosion of telecommunication demand, especially in mobile telecommunication and Internet-services has shaken up telecommunication research. The dominance of voice communication has been overruled by data-communication and gradually telecommunication engineers had to look outside, what other technologies can provide and what customers want. In the sector of business-systems and mobile communication we find several forms of user-groups, discussing new services with researchers. The sequence of idea-innovation chain has changed. Especially the role of the marketing department has changed. Their role is not so much to bring products to the customer, but rather to bring customers to product development and -design. They involve customers in the fist phases of research and build their research efforts on customers’ wishes. Customers’ demand has become the cornerstone of research and there is a tendency to break up linearity of the idea-innovation chain towards a more synchronised approach, based on customers’ demand

3.2. Biotechnology

Research in classical biotechnology can be characterised as a series of incremental innovations, but in general, its research profile was low. Improvement of breeding programmes in cattle and plants was a combination of gut-feeling and scientific insight; it was a tacit kind of knowledge, limited to specific fields. Knowledge about breeding programmes in Holsteiner cows could not be transposed on a one-to-one bases in Limousin cows, let alone in other species like pigs or poultry. The brewing of beer or the making of wine, vinegar, yeast or cheese was as little as no subject of many changes. Even in the innovations in the production of medicine, especially in the production of antibiotics, which was also based on fermentation processes, we can rather speak of incremental innovations, building on the knowledge that was provided after the discovery of penicillin, which was definitely a radical innovation. The pattern in classical biotechnology, thus, was a series of incremental, and even artisanal innovations, in known fields (to use the terminology of Whitley, 1998, p. 75). The origine of biotech production in medicine is based on a radical innovation, but its further application is a step-by-step extension of its basic principles. The discovery of how to manipulate genes in living organism in the early 1970s has added a whole new dimension in biotech research. Classical biotechnology was shaken up by this radical discovery. This technology could be applied in so many fields that biotechnology was gradually becoming an umbrella for a whole range of fields with several unexpected combinations. Initially, these techniques were uses within the classical domains, but gradually the borders between domains got blurred and horizontal links covering several technologies appeared. In plant breeding one can observe this process in the three stages of development since recombinant DNA technology was introduced. During the first stage the plants were modified to make them resistant to specific external circumstances like drought, salty soils, or the use of herbicides. In the second stage the properties of the plant itself were improved: more taste, better taste, longer storage life, etc. In the third stage new elements were added to enhance nutrition value. The impact of modern biotechnology in modern healthcare is even more spectacular. New views have struck the roots of healthcare; the human body is seen as a large organism with a wide range of functions, controlled by metabolism processes, and guided by genes. Dis-functionality, mutation or defects in genes may cause diseases, especially hereditary diseases. Large scale scanning programmes, aimed at the detection of these defects might help to diagnose disease before it is active and treat the patient by altering the deficient genes. This is really a radical change with far reaching implications. The field of genomics, which is the study how genes are organised in the genome and the functions they perform, is expanding and bringing new insight. It encompasses the mapping of the genome, research in the functioning of genes en their hereditary characteristics, and how these functions and characteristics influence the functioning of cells and whole organisms.

Research in genomics now mainly concentrates on the circumstances that trigger or activate gene-expression and how these circumstances influence the result in gene-expression, but in the future it will lead to new treatment of illness and disease. Research also concentrates on the differences that are brought forward by external influences like nutrition of the cell, the influence of chemicals, medicine, and even physical circumstances in case the study concentrates on humans. These studies may reveal the secrets of metabolism in cells, but also in larger organisms. The term *metabolomics* is often used for this type of research.

Biotech research is a booming field. Each result and each new technology allows more disciplines to enter the field. A range of new technologies have become available, like recombinant DNA technology, monoclonal antibody technology, rational drug design, combinatorial chemistry, high throughput sequencing, high throughput biological screening and DNA chip or micro array technology. These technologies are often developed in specialised laboratories, and often with such promising economic prospects that its has lead to a range of startup companies in the 1980s and 1990s. Biotech research is thus an iterative field, where each result generates a multitude of new research questions. The integration of computer technology in biotech research has especially boomed research efforts. The unravelling of the human genome has generated huge amounts of data, as well as the unravelling of other (smaller) model-organisms have done before. Computer technology has made these data accessible and its has become so much easier to scan large amounts of data. Furthermore, computer programmes have provided the technology to analyse data regarding the functioning and structure of bio-molecules (DNA, proteins, enzymes, etc.). Bio-informatics has provided the algorithms to build multi-dimensional models of bio-molecules, and thus provided the means for a comparison in this field.

3.3. The Two Sectors Compared

Knowledge is the key-word in telecommunication as well as biotechnology, especially from the 1970's on. Until then, research-activities have been largely aiming at improving existing technologies and, as technology became more complex, knowledge became increasingly important. The research setup in both sectors was relatively stable. The core of research activities was in the industry, albeit that there were - sometimes even strong - forms of cooperation with universities and research institutes. Agricultural research in the Netherlands for instance was closely tight to the sector and a system of both practical and theoretical research surrounded the sector, making knowledge easy accessible to farmers and breeders. Also in telecommunication there was a certain degree of cooperation in telecommunication research, but the gravity of research was in the telecommunication industry. In general, there was a large degree of stability and innovation was basically limited to incremental innovations. The basic principles of switching technology in telecommunication were hardly affected by innovations; they were rather improved, time and time again. In transmission technology there have been several technological changes.

Some of them have been incremental, like for instance the change from twisted pair cable to coax cable. This innovation provided an increased capacity, but it did not change the 'rules of the game'. The introduction of waveguide propagation on the other hand was a radical innovation. Telecommunication signals were propagated through radio-waves, instead of electrical signals in copper cable. Indeed, a radical change of technology, but it did not affect the telecommunication system as such. In the broader context of the telecommunication system it was seen as a in *incremental*, or *adaptive* innovation as they seek to improve existing frameworks through new combinations of relatively standardised characteristics of goods and services (fur further reading: Langlois and Robertson, 1995, Whitley, 1998). By and large we find the same situation in classical biotechnology. Some new treatments based on the use of antibiotics have been spectacular, but they are rather a further extension of existing knowledge, and thus incremental rather than radical innovation. However, for the parties involved the feeling of radicalness is often very strong, especially when a new cure has been found for a formerly incurable disease.

The invention of DNA technology was a logical next step in bio-technological research and it was in fact building on the knowledge-domain that was explored for the first time at the discovery of the DNA structure some twenty years before. As such it was not so much a competence destroyer as it was a competence enhancer. It allowed scientists to explore the secrets of DNA on a deeper level of understanding. However, the impact of this technology has been impressive. It is to be expected that innovativeness will constantly be enhanced by new combinations. The merger of engineering, technology and biology in modern biotechnology has generated new pathways in knowledge development each with a high potential in itself, but usually also with a high potential in other fields. Biotechnology has become a field of self-sustaining innovations.

The principles of digital switching were not unknown to the telecommunication industry and the introduction of digital switching equipment can be seen as a merger between the principles used in telecommunication and those in computer-science. As such, it was a logical next step in the development of ever faster machines able to handle larger capacities. Here again, the radicalness was in its effects. Digital equipment is much cheaper than analogue equipment, which has struck the roots of state monopolies in telecommunication. Thus, digitalisation of switching equipment has been the overture to a radical change in the rules of the game. Privatisation and liberalisation of the telecommunication market, together with an increasing variety and extension of services, and a technological platform allowing fast extension of services, have been the cluster of radical changes that have taken place in public telecommunication. Indeed, digitalisation has sparked the process, but the fuel was supplied by change of regulation and increasing customer demand.

However, if we try to keep track of innovativeness in modern biotechnology and telecommunication, we see some interesting differences. In modern biotechnology we can use the metaphor of firework exploding in all directions. In telecommunication, the sector is gradually taken over the profile of other sectors. Telecommunication companies rather fill their shopping baskets at specialised suppliers, than designing all components in-house. Developments in integrated circuits for instance are not so much liable to the 'laws of telecommunication' but have their own order. Technology in integrated circuits has developed into a generic technology, with applications in all fields of technology; in telecom equipment, but also in photo-cameras or washing machines. A further integration will presumably dilute the profile of the sector, and make it even more liable to the general laws in electronics. We already gave the example of a modern handset in mobile telecommunication. It combines so many features that it is increasingly hard to speak of telecommunication equipment, referring to its original property as a telephone. It is just one of the functions. It remains to be seen how the profile of the sector will change in the near future.

Telecommunication research is increasingly becoming the field of software development, and increasingly demand driven. Companies concentrate on parametric innovations in handsets, building features based on customers' preference. High dynamism with short life-cycles. This provides room for software driven ICT companies, while the established telecommunication companies reorganise their product-portfolio. Companies increasingly leave basic research the sole responsibly of universities and research institutes and concentrate on applied research and product development.

In biotechnology we find a range of research activities, involving a range of companies, universities, research groups and research institutes, often working in close cooperation. However, the pattern is not as clear as in telecommunication where we mainly find startup companies providing services with a clear scope on telecommunication end-users. Startups bridge the gap between telecommunication industry, telecommunication operators, service-providers and the end-user. In modern biotechnology we find startup activity in every phase of the idea-innovation chain, especially on the interface between basic and applied research.

In telecommunication we find a tendency towards integration of research activities. In modern biotechnology we find integration as well as specialisation, yielding a scattered pattern of research activities and research forms.

Chapter 4. Performance along the Idea-Innovation Chain

Brigitte Unger

With thanks to the research collaborators Susanne Giesecke, Christine Larson, Herman Oosterwijk, Stefanie Rossak and Mike Visser.

4.1. Introduction

How innovative are Austria, Finland, Germany and the Netherlands, in particular in high tech sectors such as biotechnology and telecommunications? Is innovativeness characteristic for the country or only for the specific sector? And, last not least, does innovativeness pay? Does innovative performance transform into economic success? Or in our project terms: Is it important to be successful at the begin of the idea-innovation chain in order to have economic success at the end of the chain?

One cannot measure innovation *as it happens*. It is a specific act that only occurs once and that can only be judged much later when it is adopted. Many actors suffer from a time bias. Expert respondents will identify many more innovations within the most recent decade than in the two or three preceding decades. The near past seems always more important than the distant past. Also the degree of modification varies. Everybody will agree that the steam engine was a radical innovation. But are minor modifications such as changes in color of the wrapping paper an innovation? And when is it an innovation and when simply an imitation? Is something new to the firm or the sector an innovation or is it an imitation of other sectors or countries?

Innovation can only be approached by proxy variables, and involves measuring problems of which only some few will be discussed. The aim is to find out the particular performance strengths and weaknesses of the four countries and two sectors studied. The first section evaluates economic and innovative performance of the four countries along the idea-innovation chain for telecommunication and biotechnology as well as at the national level. The second section gives an overview of the four countries' characteristics and sector specialization. The third section derives some country and sector puzzles from the performance and sector specialization results.

4.2. Innovative and Economic Performance along the Idea-Innovation Chain

The idea-innovation chain, identified by Hage and Hollingsworth (1999), starts with basic research followed by applied research, development, manufacturing, quality control and ends with the marketing and commercialization of the product. Since measures do not exactly distinguish between the six phases of the idea-innovation, they will be attributed to three phases of the chain. The beginning of the idea innovation chain, notably basic and applied research and development, the middle of the chain which builds on the research results and the end of the chain with production and sales. It is diffusion, the end of the chain, that counts for the economic success, not innovation. There are in principal five ways to measure innovation along the idea innovation chain:

• 1. Research and Development expenditures and other input indicators
• 2 . Patents

• 3. Literature Based Indicators (innovations quoted in trade journals and publications)
• 4. Surveys (with all the bias problems related to them)
• 5. Sales of Innovative Products and Other Output Indicators

Figure 4.1. Measures of Innovative Performance along the Idea-Innovation Chain:

basic research	applied research	develop-ment	manu-facturing	quality control	marketing and sales

R&D and other input Indicators	**Patents** **Literature Based Indicators**	**Surveys**	**Sales, Exports**

4.2.1. The Beginning of the Idea-Innovation Chain: Research and Development

The first three links of the chain, basic and applied research and development can be proxied with R&D expenditures or R&D personnel. These are input factors and measure the effort to innovate, but not whether these efforts were actually successful. R&D is the most heavily used indicator of all innovative performance indicators. It is collected and standardized by the OECD and easily available (e.g. 1998, Science Technology and Industry Outlook, p.167). However, the innovation process entails much more than R&D, notably design, marketing, tooling, and prototyping. Therefore, the input factor R&D accounts for only about half of total innovation expexpenditures (Kleinknecht 1996). Market surveys, trial production, tooling-up, training, the preparation of the distribution chain**,** designs, patents and licenses all account for total product innovation expenditure. Big measurement problems are due to subsidy schemes.

Another criticism is that R&D oriented measures cannot deal with activities of the firm that are directed towards knowledge accumulation. There are measures of capital intensity, technology intensity, but not of “knowledge intensity” (Freeman, 1994).

4.2.2. R&D Expenditures in the Four Countries

At a national level, Finland is leading in R&D intensity. Sweden and Finland rank top among all OECD countries and even surpass the US. Austria is on the other side of the scale, and only recently makes some efforts to increase its R&D. But so do the other countries , which leaves the ranking over the last years stable (in 2000: FIN:3.1%, D: 2.4%, NL:2%, A:1.8% of GDP) (see OECD STI 2001).

Apart from differences in government involvement (see Chapter 7 on institutions), it has to be noted that the Netherlands depends much more on the financing of R&D from abroad than the three other countries. In the Netherlands 7.6% of R&D expenditures is financed from abroad, as compared with 4.5% in Finland, 4% in Austria and 1.8% in Germany:

From input indicator R&D expenditures one can see that at a national level the ranking is: **FIN-D-NL-A.** At the beginning of the idea innovation chain Finland and Germany are stronger than the two other countries.

Does this result also hold for the two high tech sectors? As we will see, in principle yes, though the Dutch play a more important role in telecommunications.

4.2.3. R&D in Telecommunications and Biotechnology

The paradigm shift in telecommunication resulted in a reshaping of the traditional R&D process. Basic research loses importance. Firms close their own R&D departments and internalize external research institutes. Today, many network operators do not invest in R&D, whereas equipment manufacturers have shifted their R&D from research to development in order to increase their competitiveness in a short term perspective.

The companies interviewed by our study had on average the following R&D intensity. However, some global players (such as Siemens Germany) seem to have given their global research personnel and expenditure data. (e.g. 113000 people in research). Furthermore, we do not know how representative our data are for the whole sector. But if for the time being we believe the data in 2000, Finland has the highest R&D intensity. In equipment manufacturing Finland leads with R&D accounting for 18.85% of turnover, followed by Austria (15%, which seems very high) and Germany (8.5%). Unfortunately data for the NL are missing. But the guess is that it ranks high.

Table 4.1. Telecommunication Sectors of the Four Countries compared in 2000 or latest data available

Country	Nr. Firms	of which studied	Employment	Turnover in mio EU	R&D Employment	Labor Prod.in mio EU	R&D in % turnover
Austria	40	9	50000	8595	4245	0.45	0.22
Finland	120	14	51000	17,538*	12600	0.22	0.32
Germany	137	14	368000	147460	6715	0.19	0.42
Netherlands	301	..	129,000*	..	..	..	..

Source: Country reports and the author’s own calculations. * refers to total sector numbers, otherwise the data refer to the firms studied. For Finland the turnover of the ICT cluster is 17,538 mio Euro, the 14 firms studied had a turnover of 11,100 mio Euro, i.e. about two thirds. In Austria the nine firms studied account for more than 90 percent of the market. In Germany only research intense firms and no services have been included in the study. For the Netherlands too many data were missing. Dutch value added in the telecom sector was 11,572 mio Euro in 1999, with carrier services having the lion’s share of 9,189 mio Euros.

For telecommunications we can conclude that reliable R&D data were not available. For the ranking we can safely believe that Finland and the Dutch play a very important role . This is also reflected in other input indicators such as total innovation expenditures. From CIS data we know that in 1996, total innovation expenditures in % of turnover were the highest in the Netherlands (9.9%), 7.4% in Finland, 5.7% in Austria and 5.6% in Germany in electronics (see Polt et al 1999, p.19). This leads to the rank-order: NL-FIN-A-D. Also in the telecom service sector are innovation expenditures the highest in the Netherlands (11%), followed by Finland (3%) and Germany (1.8%). Austria’s total innovation expenditures are the lowest (0.3%). NL - FIN- D-A

From the table summarizing the performance data on biotechnology one can see that the highest R&D expenditures in pharmaceuticals in percent of turnover are in Finland (16.6%), followed by Germany (9.35) and the Netherlands (8.1%). Data for Austria are missing but one can assume quite safely that it ranks last. **FIN-D-NL-A**.

For green biotech we can only refer to R&D in the food industry. Here the Netherlands (and Finland) show a higher R&D intensity (0.6) than Germany (0.2). Data for Austria are missing.

4.2.4. Indicators for the Middle of the Idea-Innovation Chain: Patents and Literature Based Indicators

Patents are a widely used indicator for innovation**,** although a patent is the result of invention and not of innovation. It is not clear whether it is an input or an output, since it can also be a throughput. Cohen and Levin (1989, p.1063) point at the significant problems with patent counts. Most notably, the economic value of patents is very heterogeneous. A great majority of patents are never exploited commercially, and only very few are associated with major technological improvements. Moreover, a patent might consist of several related claims, each of which might be filed as a separate patent. US inventors tend to bundle claims into one patent, while the Japanese typically file separate patents for each claim.

The propensity to patent varies across industries. Many sectors do not patent at all. In particular service sectors (repair services, transportation, communications, banking and insurance) have a high share of non patentable innovations. Other service sectors (ship transportation, wholesale trade and intermediary trade firms) develop few innovations themselves but apply for patent protection of the products they are selling (Kleinknecht, Reijnen and Smits 1993, p.55). Patents are very important for the pharmaceutical and chemical industry. But in the electronic industries, entire categories of economically significant innovations are typically not patentable. Computer software, for example, is normally capable for copyrights, but not for patent protection. There is a serious trade-off between patenting innovations and keeping them secret. In some industries, patents reveal information to the competitor that cannot be ascertained by other means (e.g. reverse engineering the product). By contrast patents may be preferred, where they serve as "signals" of technological competence to sponsors and suppliers of capital. For a critical discussion on the use of patents as an indicator for innovation, see Pavitt (1985), Cohen and Levin (1989), Griliches (1990) and Kleinknecht (1996).

National patent offices do not classify patents by industry but by products. Sectoral patent statistics have, therefore, first to be composed. There is also a size bias. Small firms patent only after having overcome a threshold. Where firms patent is also not clear, small firms patent mostly only domestically, larger firms domestically and in the US. This leads to biases towards large firms when using US patent statistics.[2]

Patent application data show the effort of firms to protect their intellectual property, but applications can get refused. Patents granted might underestimate the innovation efforts.

About half of all patent applications are successful. In 1998 9108 patents were granted in Germany, 1253 in the Netherlands, 599 in Finland, 398 in Austria, compared to 80,009 in the US. No country comes close to the US, which accounts for about 60% of all patents in the world.[3] Partly, this is due to the bias that US patent statistics refer to domestic patenting of US firms (whereas to patenting abroad for all other firms) and to the country size. But efforts done to correct for this bias (by including Japanese and European patent statistics) still confirm the

1. I owe this point to Alfred Kleinknecht.

2. See US Patent and Trademark Office, Patent Counts by Country and Year, all patents all types 1977-1998. In 1995 from 113955 patents granted, 64510 were from the US, 359 were granted to Austria, 387 to Finland, 6874 to Germany and 894 to the Netherlands.

hypothesis that the US is highly innovative. [4]

When patent applications are ranked in terms of labor force in order to correct for country size, Germany leads with 367 patents per million of worker (including the unemployed), followed by Finland (with 348), the Netherlands (with 275) and Austria (with 203).
The ranking of the throughput or output factor patents is **D-FIN-NL-A**, where the first two countries lie closer together than the third and fourth. When compared with the input data, Finland and Germany have changed places.

One can conclude that at the first part of the idea innovation chain Finland and Germany are stronger than the Netherlands and Austria. Both, input and throughput/output indicators indicate the strength of the first two countries at a national level.

Does this also hold for the two science based industries? No, Germany moves back to the third place in both sectors and the Netherlands take the lead in biotechnology.

4.2.5. Patents in Telecommunications and Biotechnology

In Electronic Equipment the Netherlands (24.3%) rank much higher than all other countries. Finland has 9.1%, Germany 8% and Austria 4.9% of manufacturing patents in this sector (see CHI Research). In the ICT sector Finland is leading, with patents at the US Patent and Trademark office (USPTO) being 3% of GDP in 1999, followed by the Netherlands (0.85%), Germany (0.6%) and Austria (0.15%) (see OECD STI 2001, p.82). Patents became on the one hand increasingly important for electronic equipment which makes about 10% of a country's patenting. On the other hand, the paradigm shift in telecommunication meant a shift from hardware to software. The use of software required a different knowledge codification and is protected by intellectual property rights such as copyrights rather than patents. But the overall effect seems to be a rise in patents.
Performance in ICT patents: **FIN-NL-D-A**

In pharmaceuticals, Germany has by far the highest amount of patents per mio inhabitants (65.7), then there is a big gap with the Netherlands (22.2), Finland (19.6) and Austria (18.5 being quite similar. **Pharmaceuticals: D-NL-FIN-A**. For food one can see the outstanding performance of the Netherlands with 20.2 patents per mio inhabitants. Austria with 3.9 lies at the low end. **Food: NL-D-FIN-A**

Lately, the OECD has developed a sector classification for **biotechnology** (red and green and grey). Based on US and European Patent Statistic Office data, the ranking of the four countries for patents granted by the USPTO and patents applied to the EPO in 1990 and 2000 is D-NL-A-FIN. But this is more the size effect of the countries than their idea richness. When divided by the number of inhabitants, the ranking turns into **NL-FIN-D-A** , where Finland and Germany lie close together. Germany's leading role in pharmaceutical patents, does not seem to hold for the broader definition of the biotechnology sector (see OECD van Beuzekom 2001).

---

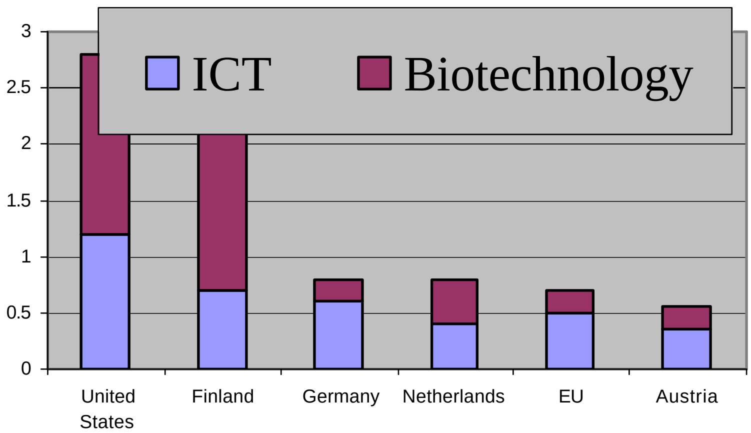
3. I owe this point to John Cantwell.

Table 4.2. Number of Patents, Sum 1975-1999 per million inhabitants

	Austria	**Finland**	**Germany**	**Netherlands**	**USA**
Total Manufacturing Industry	854.8	926.6	2621.9	1214.4	4426.3
Food, Drink & Tobacco	3.9	9.8	10.7	20.2	35.5
Textiles, Footwear & Leather	4.9	4.7	22.0	7.5	26.7
Chemicals	122.9	118.1	660.7	257.2	871.7
Pharmaceuticals	18.5	19.6	65.7	22.2	100.2
Stone, Clay & Glass	17.8	20.9	48.3	21.6	83.0
Basic Metal Industries	23.2	15.5	26.7	8.2	37.6
Fabric. Metal Prod. and Machinery	575.4	658.2	1733.4	850.0	2938.4
Office Machinery & Computers	14.2	9.4	55.4	38.7	158.9
Electronic Equipment & Components	41.8	83.9	210.9	295.5	559.5
Shipbuilding	1.1	7.3	4.7	4.3	15.2
Motor Vehicles	22.1	13.3	89.4	11.8	81.0
Aerospace	11.0	4.5	40.3	4.5	43.6
Other Transport Equipment	8.6	6.1	25.2	3.3	34.4
Other Manufacturing	106.9	99.9	120.1	49.6	433.6

Source: CHI Research

Figure 4.2. Patents in ICT and Biotechnology relative to GDP 1999



Source: OECD (2002) Science, Tecnlogoy, Technology and Industry Outlook

4.2.6. Literature Based Indicators (innovations quoted in trade journals and publications)

Another route for evaluating the output of ideas is to cumulatively establish a list of all known significant innovations in a period through trade journals and scientific journals. There have been quite extensive studies on Literature-based Innovation Output Indicators. Kleinknecht and Bain (1993) present an overview of the use of these indicators in diverse countries. Disadvantages are that it is cumbersome to create the database, and that the comparison with journals of other countries is not possible.

CHI Research, an American private research institute led by Francis Narin, has created a database on patents which includes the number of science references cited on the front page of a company's patents (=science strength) and allows to identify high tech players from improved design innovators (less or no references to science). Science strength by employee correct for size and can be used as a proxy for "importance" or "radicalness". Finland (437 scientific references per employee on the front page of patents) and the Netherlands (289) are leading, followed by Austria (255) and Germany (227). The scientific linkage of the US is, however, much larger (1928).

The number of times a company's previous five years of patents are cited in the current year, relative to all patents in the US patent statistics (=current impact index, 1 represents average citation frequency) is higher, the more important (radical) the invention was. The US is above average (1.14), followed by Finland (0.77), the Netherlands (0.71), Germany (0.58) and Austria (0.50). In particular the strong catching up of Finland since 1986 is remarkable, indicating a high degree of radical innovations in telecommunication in this country. Also the citations received by a company's patents from subsequent patents allows to assess the technological impact of patents. High citation counts are often associated with important inventions. The ranking is again US-FIN-NL-D-A. The same ranking for the four countries under consideration holds for the average technology cycle time, where Finland even surpassed the US.

4.2.7. The End of the Idea-Innovation Chain: Survey Studies and Sales of Innovative Products

In the 1960s universities started fairly extensive surveys of innovation, in particular in the US (Mansfield 1968 in Pennsylvania, Myers and Marquis 1969 at the MIT). In Sussex ,UK, Freeman (1971) and Townsend (1981) surveyed thousands of innovative outputs and interviewed experts (Debresson 1996, p.9). Large surveys on innovative activity have been done recently by the European Community (CIS -Eurostat).

Though we are content with the increasing amount of survey data, there are still some serious methodological problems remaining. All surveys of innovation find an unexpected number of respondents who claim to have introduced new or improved products or processes that were not only new to the firm but also new to the country and even to the world. Debresson (1996, p.47) quotes surveys, where 20% to 40% of the national first respondent firms claimed that they were also world firsts. "One can be skeptical about respondents' view regarding their own accomplishments and be reasonably sure that they are biased in claiming that they have done what is good, right and fashionable to do - innovate" (Debresson 1996, p.47).

Beside this psychological factor of self-esteem, some further cognitive psychological facts play a role: our perception is dependent on the reference system. The answers are likely to overemphasize the local, closer environment. Furthermore, innovators often do not know whether the industry also innovated, i.e. they cannot distinguish whether an innovation is new to the firm or to the industry. Finally, the time bias of overemphasizing the importance of most recent changes, has already been mentioned in the beginning.

To the potential bias of overestimation of innovations, a cultural bias has to be added, which might be labeled the "Dutch modesty effect". To give an example, when asked to indicate, which objectives were very important for innovation, the Dutch tend to cross less items than do other countries.[5] Whereas the Austrians like to exaggerate and avoid the middle categories.

Recently, the European Community did a representative survey for all member countries:

4.This "Dutch modesty effect" can also be found in other comparative studies. The results of the World Value Study, for example, show that the Dutch, when asked to rank between 1 and 10 whether they find something very good or very bad tend to cross in the middle and to avoid extremes.

the Community Innovation Survey 1996 - *CIS II* (1999), which provides data at the firm and sectoral level. Also in the CIS data Austrian firms appear more active than one would assume intuitively and Dutch firms less active.[6]

Of all enterprises surveyed, 69% called themselves innovative in Germany, 67% in Austria, 62% in the Netherlands and only 36% in Finland. The same ranking holds for product and process innovators.

Compared with the input and patent data, Finland seems to be much less innovative in survey data. The high input and output numbers might thus belong to very few firms, whereas the other countries have a larger spread. The Finish success seems due to outliers such as Nokia in telecommunications. We end up with the innovativeness ranking of **D-A-NL-FIN** from the survey data, however, differences are much larger between Finland and the rest than among the three other countries.

For telecommunication, we can use failure rates as a proxy. **Failure of projects is very high in the Netherlands and Finland** for **telecommunication** services. It seems that the most innovative countries also experience the highest share of firms that report failures of projects. In the telecom sector the failure rate ranks NL-FIN-D-A (data for Austria are missing for this variable).

The CIS II data did not include biotechnology as a category. However, in **food, beverages and tobacco** Germany has the highest share of product innovators among reporting firms (69%) followed by Austria (60%), the Netherlands (50%) and Finland (22%). But, as we know, the Germans are not strong in green biotechnology.

The failure reports can be a good indicator for innovative activities in a sector. From this, Germany is leading in food, followed by the Netherlands, Finland and Austria **D-NL-FIN-A.**

If we take from the CIS data the chemical industry as a proxy for red biotech, we find that the Netherlands and Germany are leading and Austria and Finland are behind.
Given the fact that the sector definition is far too broad for biotech and that the results are also somehow doubtful (Austria is more innovative in food than the Netherlands!) the survey ranking was only included for the sake of completeness.

At the end of the idea innovation chain we find sales of innovative products. This is the only direct indicator of innovation. The problems that arise with it are listed under survey data. In particular the overestimation bias (time bias and others) that has been discussed in the beginning, is problematic here.

The largest share of innovative turnover has Germany (49%), followed by Austria (37%) and Finland and the Netherlands (both 32%). The innovative sales ranking is **D-A-NL=FIN.**

4.3. Economic Performance: Productivity, Competitiveness and Exports

Can countries and sectors be economic successful without innovativeness or must they be strong at the beginning of the chain or at least at the end where they sell innovative products?

Economic performance will be evaluated by means of labour productivity (output per employed or per working hour) and by relative unit labour costs, an indicator for the competitiveness of a country and by export performance (measures partly also competitiveness).

At the national level GDP per person employed as % of OECD average shows that all four

5. The survey was done for all EU-15 countries and consisted of 30 questions. (The precedent CIS I survey was done for EU-12 countries and consisted of 200 questions. Unfortunately, Austria and Finland were not included in CIS I). The population was 133284 enterprises in the four countries, of which 37004 enterprises in German manufacturing and 79602 in services, in the Netherlands 6903 in manufacturing and 11443 in services, in Austria 4139 in manufacturing and 5348 in services and in Finland 2285 in manufacturing and 2182 in services. The realized sample in % of the population differs quite substantially. It was 5% in Germany, 20% in Austria, 40% in Finland and the Netherlands. The German sample size is far below the EU average of 16%.

countries have a relatively high **labor productivity**, Germany and Austria take the lead followed by the Netherlands and Finland. But the US ranks even higher. Labor productivity as measured in GDP per hour worked puts the US in a far less favorable position, since it corrects for the more relaxed working time arrangements in Europe. The high amount of part time jobs puts the Netherlands in a favorable position. Labor productivity in the Netherlands is 132, in Germany 121, in Austria 112 and in Finland 103 compared to 110 in the US (see table on national performance).

Finland had been catching up since 1970 and even surpassed the OECD average in 1990. But with the economic slump around the turn of the decade, with growth rates of -7% in 1990, the picture changed radically. The loss of the Russian market had its imprint. Since then Finland catches up again rapidly.

Relative Labor Unit Costs are an indicator for the competitiveness of the country on the world market. The lower the relative labor unit costs, the higher competitiveness. Between 1980 and 1997 relative unit labor costs have continuously fallen in Finland, followed by Austria and the Netherlands. Only Germany experienced a continuous increase in relative labor unit costs (see national table and OECD 1998, p.357).

Exports are another important indicator in order to measure diffusion. Very often this measure is used for competitiveness and specialization comparisons of countries. Balassa's (1965) Revealed Comparative Advantage index (**RCA**) shows the relative share of a sector in a given country's total exports compared with the relative share of the sector in world's exports. In particular for sectors difficult to trace, such as biotechnology, this indicator is helpful. Disadvantages are that big countries, such as the US might be much less dependent on exports than small open economies. Domestic sales have the same positive effect on GDP as foreign sales do. Exports do not tell us much about innovation. A country with a large amount of raw materials can be a heavy exporter, but not innovative. Indicators such as **technology intense exports or technology balances** (exports minus or divided through imports) try to account for this problem. One problem with all trade statistics is that they are heavily biased. In 1995, a comparison of technology exports through imports reveals that the US (3.96) is a net exporter, whereas all four countries are weak in technology receipts, three of them are technology net importers, and the Netherlands are balanced (1.01) (see Table 1), NL-D-A-FIN.

4.3.1. Telecommunications

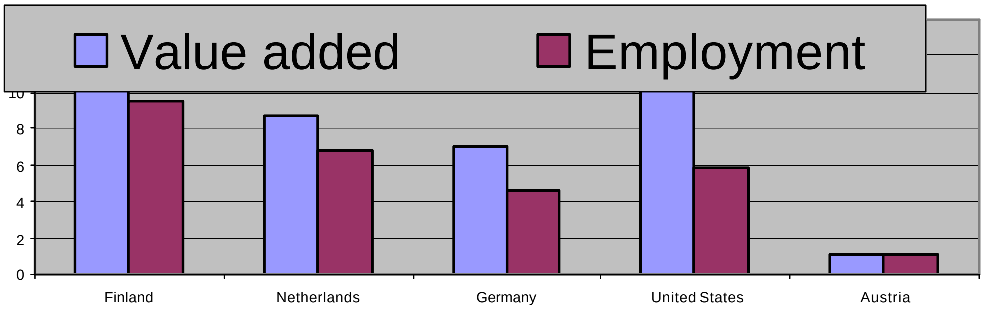
Labor productivity can be measured as net value added per employee. The gross value added, i.e. turnover, is sometimes used as a proxy but can be misleading since it does not deduct the inputs to production. If a country imports mobile phones and sells it, there can be a high turnover but almost no value added. Labor productivity is than overestimated.

Since MNEs place their researchers in one country and their production plants in another it is difficult to evaluate labor productivity. The country with the researchers will have little turnover and labor productivity since production and sales take place somewhere else. The country with the production plant will profit from the research results of the other country and will have an overestimated labor productivity.

Some other proxy for labou\r productivity are labor costs under the assumptions that workers get paid according to their (marginal) labor productivity as is the neoclassical efficiency assumption. By 1995 the revenues per employee are the highest in the Netherlands ($242,473), followed by Austria ($220,962), Germany ($197,810) and Finland ($173,108). This ranking is the same for the number of access-lines per employee (NL 271, A 235, D 230, FIN 219) and did not change since 1990.

From the proxies for labor productivity one can conclude that the Netherlands are leading, Austria and Germany lie in the middle and Finland at the bottom of the ranking **NL-A-D-FIN.** For exports see under performance and paradigm shift below.

Figure 4.3. ICT Industries Account for a Significant Share of Economic Activity



Source: OECD (2002)*Science, Technology and Industry Outlook*

4.3.2. Biotechnology

Biotechnology is partly not at the stage of being a finished product. Most activities concern the beginning of the chain. In green biotech field trials are forbidden in some countries. In pharmaceutical the development of a drug takes up to twelve years, the product is hence not yet finished. And in diagnostics very often what is sold is not a product but knowledge, or so heterogenous products that sales would not tell much. There are some single products that account for enormous amounts but it would be difficult to evaluate the sector.

In Finland, in 1999 **turnover** of biotech (excluding big pharma companies) were 1313 mio PPP US$ and employed about 4000 people. Including the three big pharma companies employees twice as much. In Germany biotech employed 16000 people in the same year. In the Netherlands 1615 people worked in biotech R&D (see OECD van Beuzekom 2001). Austria is missing in this data collection.

(West) Germany is among the top 4 produces of **food products** (1995: 6.4% of world total value added). Only the US (24%), Japan (14.8%) and France (6.6%) lie ahead. However, the Netherlands’ figures are also prominent with food products on the world market. Its world market share is 1.8% in both 1985 and 1995 Exports World Leading Producers in 1985 and 1995 (Source: International Yearbook of Industrial Statistics 1998,UNIDO, Vienna 1998). Germany and the Netherlands are also strong in **chemicals** (Germany has rank 3 with 12.7% of industrial chemicals, the Netherlands has rank 7 with a world market share of 3%).

To conclude, from the five different ways of measuring innovation we get five rankings that indicate different patterns of innovation, which will be investigated in the following sections.

National

Input Indicators R&D	FIN-D-NL-A
Patents	D-FIN-NL-A
Literature Based Indicators	FIN-NL-A-D
Survey data	D-A-NL-FIN
Sales of innovative products	D-A-NL=FIN
Labor Productivity	D-A-NL-FIN
Technol. Exports//Imports	NL-D-A-FIN

Telecommunications

R&D	missing
Patents	NL-FIN-D-A
Survey	NL-FIN-D-A
Labor Prod.	NL-A-D-FIN
Exports	FIN-NL-D-A

Biotechnology

R&D	FIN-D-NL-A (pharma)
Patents	D-NL-FIN-A (pharma)
	NL-D-FIN-A (food)
	NL-FIN-D-A (biotech)
Survey	D-NL-FIN-A (chemicals)
Labor Prod	missing
Exports	D-NL-FIN-A

With regard to overall economic performance we can conclude that Germany and the Netherlands are comparatively high productivity but high wage increase countries, and Finland is a comparatively low productivity but lower wage increase country. Austria ranks in the middle. It is second or third best in productivity,, depending how it is measured and it has a quite favorable competitive development as expressed by the change in relative labor unit costs. Austria does better in economic performance than in innovative performance.

Table 4.3.a. National Innovative and Economic Performance Along the Idea Innovation Chain

	Austria	Finland	Germany	Netherlands	US
Input Indicators: R&D in % of GDP 1997	1.52	2.73	2.39	2.09	2.64
Total innovation expenditures in % of all enterprises 96	3.5	4.3	4.1	3.8	..
Output Indicators: No. of patents granted 1996 Patent applications per mio of inhabitants 1996	398 50	599 117	9108 112	1253 81	80009 306
Survey (CIS): innovating enterprises (in % of all enterprises)	67	36	69	62	(EU: 53)
unsuccessful/not completed projects (in % of all) Innovative products in % of all products (in turnover) 1996	29 37	34 32	33 49	38 32	(EU: 28)
Literature Based Indicators: number of references in patents to scientific journals and per mio employees 1998	879 255	904 437	7923 227	1754 289	
average cites per patent 1998 Current Impact Index 1998 Current Impact Index 1986	2.1 0.50 0.72	3.2 0.77 0.61	2.1 0.58 0.85	2.4 0.71 0.91	3.9 1.14 1.01
Economic Performance: Productivity per employee, and per hour worked 1996 (100= OECD average)	102 112	99 103	105 121	99 132	125 131

Sources: OECD STI Outlook (1998), Community Innovation Survey, US Patent Statistics, CHI Research.

Table 4.3.b. Innovative and Economic Performance along the Idea Innovation Chain in Telecommunications

Performance Indicator	**Austria**	**Finland**	**Germany**	**Netherlands**
Innovative Performance				
R&D expenditures in % of GDP 2000	..	1.24	0.31	0.33
Patents in Electronic Equipment in % of Patents in Manufacturing	49	91	80	243
No. of Patents Granted in electronic equipment and components (sum 75-96 per mio inhabitants)	41,8	83,9	210,9	295,5
Survey (CIS):				
Total Innovation Expenditures	0,3%	3,0%	1,8%	11,0%
Percentage of innovative firms that cooperate	15%	76%	5%	62%
Economic Performance				
Export/Import 1962	1,44	0,14	2,81	0,91
Export/Import 1990	1,03	0,99	0,95	0,87
Penetration of mobile phones 1997	14%	46%	10%	12%
Revenues per employee in 1000 $ in 1995	220	173	197	242
Increase in Value Added per Employee 1985-90	47%	81%	27%	14%

Source: CHI Research, OECD Stan Database,
OECD Communications Outlook 1997 and 1999, UN Yearbook of International Trade Statistics,

Table 4.3.c. Innovative and Economic Performance along the Idea Innovation Chain in Biotechnology

Performance Indicator	Austria	Finland	Germany	Netherlands
Innovative Performance				
R&D expenditures in % of turnover pharma 96	..	166	93	81
R&D expenditures in % of turnover food 96	..	6	2	6
Public Funding: R&D biotech/total R&D 97	15	81	67	25
No. of Patents in Pharmaceuticals (sum 75-96 per mio inhabitants)	18,5	19,5	65,7	22,2
No. of Patents 2000 USPTO in Biotech Related Fields (per mio inhabitants)	2	6	5	9
Patents Granted by USPTO 1990	5	8	100	18
Patents Granted by USPTO 2000	25	20	200	47
Biotech Patents Application EPO 1990	13	10	150	25
Biotech Patents Application EPO 1997	14	11	240	50
Deliberate Releases of GMOs 1992-2000	3	16	102	117

Sources: CHI Research, OECD van Beuzekom Sept 2001

4.4. Performance Changes: Telecommunications in the 1960s, 1980s and 2000

Telecommunications experienced two dramatic shifts since the 1960s. First, the paradigm shift from the electro-mechanical, analogue to the digital system in the 1980s and lately with the development of GSM. This had strong impact on the sector definition. Most of our data refer to the first paradigm shift, which was at the center of our study, but some include also the second shift since 1999/2000.

Telecommunication has become a sector that can be found both in manufacturing and in services. The digitalization of communications equipment and the increasing share of software in network technology have contributed to the fact that the sector boundaries became blurred and that services become more and more important. The distinction between hardware and software has faded since a lot of hardware needs embedded software, such as integrated circuits. The sector definition of telecommunication changes. Original it was separated into data, voice and video. In 2000, the European Information Technology Observatory (EITO 2000) has divided the ICT field into a data and a voice section.

As far as possible, data have been taken for telecommunications alone, but in particular recent data for the Netherlands and Finland often include the whole ICT sector.
Has the performance of the countries changed as a result of all the dramatic technological events?

4.4.1. Digitalization

Digitalization was first completed in the Netherlands in 1995. Finland was second. In 1995 90% of its system was digitalized. Germany's digitalization effort for the new Laender shows an a rapid increase between 1994 and 1997, when according to German plans digitalization had to be completed. Austria, though it was the first country to start digitalization in the 1980s is a laggard and finished digitalization only by 1999. Completion of digitalization: NL-FIN-D-A.

Table 4.4. Percentage of digitalization in four countries, 1990-1997

Country	1990	1992	1993	1995	1997
Austria	11	27	54	72	82
Finland	28	51	62	90	100
Germany	12	30	41	56	100
Netherlands	33	86	93	100	100

Source: OECD Communications outlook 1997: 54; 1999:77

4.4.2. Penetration of Mobile Telephones and Internet in the 1990s

Most dominant in the field of telecommunication is the development of mobile telephones and a mobile telephone network. Next to the cable-network, a whole new network of mobile telecommunication was developed, which grew dramatically during the nineties. By 1997 the number of cellular mobile subscribers was absolutely the highest in Finland with approximately 46 subscribers per 100 inhabitants, on a distance followed by Austria with 14 subscribers, then the Netherlands (12 subscribers) and Germany (10 subscribers). If we compare the penetration of mobile telephones for the four countries, there is a huge gap between Finland and the other three countries.

With regard to internet hosts per 1000 inhabitants, Finland is leading with more than 55 of

Internet hosts and shows an enormous increase since 1995 in penetration density. The Netherlands rank next with 17, followed by Austria 11 and Germany 9 (see table). **FIN-NL-A-D**.

Table 4.5. Number of Internet Hosts per 1000 Inhabitants

	Austria	Finland	Germany	Netherlands
1997	11,43	55,51	8,84	17,5
1996	8,83	54,27	6,71	13,89
1995	5,06	21,9	4,29	8,76
1994	2,51	9,75	1,83	3,88
1993	1,47	5,34	1,13	2,33
1992	0,82	3,12	0,54	1,39
1991	0,27	1,74	0,26	0,49

Source: OECD Communications Outlook 1997 Vol. 1

4.4.3. Labour Productivity

Between 1985 and 1990 labour productivity increased most dramatic in Finland (by 81%), followed by Austria (47%), Germany (27%) and the Netherlands (14%). The most impressive growth is in Finland but also Austria performs well. The Netherlands fall behind the rest. FIN-A-D-NL. The change of top and last place between Finland and the Netherlands can be partly due to the fact that it is easier to grow fast from little.

Table 4.6. Value Added per Employee - index 1975 = 100

Year	Austria	Finland	Germany[7]	Netherlands
1975	100	100	-	100
1985	232	421	100	242
1990	342	762	127	276

Source: OECD Stan 1995

4.4.4. Export Performance

Germany and Austria were strong net exporters of telecommunications equipment in the 1960's. Finland was primarily a net importer. In the 1970's Nokia in Finland started researching radio transmission and producing switching networks which could explain a part of the jump in their ratio through exports.

6. base year for Germany is 1985

Table 4.7. Export/Import Ratio for telecommunications equipment

Year	Austria	Finland	Germany	Netherlands
1962	1.44	.14	2.81	.91
1975[8]	1.02	.49	1.6	.94
1990	1.03	.99	.95	.87

Source: UN Yearbook of International Trade Statistics, OECD Stan Database

The two net exporters' performance dropped in the mid 1970s. In the late 1980s Nokia was the third largest producer of televisions in Europe. This would also explain the second Finnish jump in the export through import ratio. Their production of mobile telephones did not take off until 1992.

Since 1996 Finland has become a net exporter of telecommunications, in particular due to equipment. Finland has become the world leader in high tech trade surplus (ratio of high-technology exports/imports) among indigenous high-technology producers (OECD 2001, p.23). Finland (and Sweden) even managed to surpass Japan with regard to telecommunications export specialization in 1998 (OECD 2001, p.24).

Also Export/Import Ratios in **Electronic Industry** for the 1990s show that Finland turned from a net importer into a net exporter . In 1995 the **export/import ratio** was 0.65 in Austria (the same as in the US), 0.93 in Germany, 1.12 in the Netherlands and 1.47 in Finland.

1960s: **D-A-NL-FIN**   1990s: **FIN-NL-D-A**

With regard to export performance one can see that there was quite a change in rank places. Finland moved from the last place in the 1960s to the first place in the 1990s. The Netherlands improved its position and moved from place 3 to place 2. Germany lost its top position and moved to rank 3 and Austria lost its place 2 and moved to the last place.

With performance data one must keep in mind that Germany's strength can have been in network operating., whereas the data refer to equipment only. Germany might thus be underrated.

4.4.5. New Strengths, Niches and Weaknesses of the Countries in Telecommunications

Austria: Voice processing and smart antennas are successful Austrian niches. Voice processing was one of the highlights of Siemens research in Austria. Geographic proximity to the East, know how of trade with Eastern Europe, high educational level, cheaper labor costs than in Germany weree the assets. Weaknesses were the small size of the country, late restructuring and no experience with multinational global players. Newcomers use Austria as a sales department and not for research, lack of venture capital.

Germany is strong in equipment manufacturing of traditional communications equipment, i.e. switching and transmission technology for fixed-line communications networks. Its good universities and personnel as well as excellent public research institutes and high funding attract MNEs to settle parts of their research activities in Germany. It reacted late to technological change and lacks dynamics.

[8] Figures for 1975 and 1990 are for Radio, TV & communication equipment

Finland is strong in equipment manufacturing and electronic components of it. Manufacturing accounts for about two thirds of the Finnish ICT cluster, telecommunication services for about one fifth. Finnish telecommunications had traditionally more firms and competition and was less sheltered. Till the 1980s competition in the equipment market was allowed and foreign manufacturers such as Siemens, Ericsson and ITT set up production facilities in Finland. The Finnish telecommunication is highly concentrated, though Nokia is not the only big player anymore.

It has found a broad niche of equipment manufacturing. Finland's Its weakness is the high risk strategy of depending on so few sectors and firms. The smallness of the country has to cope with big sized players. To give an example: in the 1970s the turnover of the Siemens Group was 2 billion of Euros, almost equaling the Finnish public budget of 2.5 billion of Euros (Paija, p. 25 in: OECD Innovative Clusters 2001)

The Netherlands: Dutch telecom lacks a manufacturing industry. Dutch have no product development in telecommunications (but semiconductors etc), they are very weak in traditional telecommunications but expand rapidly in radio and CableTV, i.e. in other domains of the ICT sector. They are producers and traders of knowledge rather than products as both, their high patenting rate and their high imports in R&D reveal.

4.5. Sector Specialization and Technology Lock in

Why do countries differ in their ranking on economic and innovative performance, why do different innovation indicators point in different directions and why do firms in some countries are more inclined to engage in risky innovations than in others?

Explanations given by economists refer to technological differences, market structure and competition. For this they distinguish high-tech from low tech, and sheltered from exposed sectors (see e.g. Freeman 1994). The recent literature on national innovation systems stresses institutions as an important factor (see e.g. Lundvall 1992 and Edquist 1997). But may be it is not institutions? May be it is technology and geophysics that explains why some countries perform better than others?

In the following section, differences in sector specialization and technology lock in will be discussed. Perhaps some countries perform simply well in R&D because they have specialized in high tech sectors such as telecommunications, and may be others perform poor because they are strong in non research intense fields. Perhaps it is not the national system of innovation that explains performance differences, as we claim, but only technology? As we will see, even sector specialization is due to a specific set of institutions. Last not least the dynamics will be studied. Some countries are locked in their technologies and production patterns and, therefore, follow historically trajectories, which can be due to geophysical factors. While others are able to escape technology lock in. They manage to profit from technological change or change in export markets. Here, again, institutions can be an explanatory factor.

4.5.1. Sector Specialization

Sector specialization can be due to the geophysical location of the country and its natural endowment with resources and other production factors. History and technology lock in plays an important role for the production structure. Public research and trade policy and other institutions, such as the training system can influence the amount and quality of factor endowment and, thus, the comparative advantage of specific production and products. Sector specialization might explain, why some countries rank higher in overall innovative performance than others. Germany might be specialized in patent intensive sectors, Finland in R&D intensive sectors and Austria in none of both.

Sectoral Production Pattern: Value Added

The production pattern measured as value added of the sector in percent of total value added reveals that the Netherlands are strong in agriculture, Finland in forest industry. The Dutch profile is in particular interesting with a very low share in manufacturing and a high share in services. Austria displays this pattern too but less extreme. Its strong reliance on tourism shows in the high service and in the hotel and restaurant sector. Germany and Finland are stronger in manufacturing than the other two countries. The latter is strong in transport and communications (see OECD 1998). The production pattern results from the natural resources and historical experiences of the country. Finland's big forests, Austria's minerals from the mountains and tourism, Dutch trade in food and agricultural products going back to the fifteen and sixteen century, and Germany's handicraft sector still shape today's production pattern. The sectoral peculiarities of each country prevail even when technologies in each sector become more similar or to put it into Archibugi and Pianta's (1994) introductory words: "countries converge by becoming more different".

Sector Specialization by Input Factor: A New Classification

A new typology of industries for manufacturing only, has been done recently by the EU. Contrary to Pavitt (1984) who categorizes the sources of innovation (science based, supplier dominated etc) this classification by Peneder (1999) distinguishes labour intensive, capital intensive, R&D intensive, advertisement intensive and mainstream manufacturing, a category which includes all inputs but none in an outstanding way, such as the machine tool industry. It has the advantage to be compatible with the NACE standard classification . The four countries display quite different characteristics in regard to these input factors.

According to the findings of Peneder (1999), 1. **marketing driven industries are characterized by lower investments in R&D**. The poor input indicator performance results of the Netherlands can thus be due to its high share in advertising intensive industries such as the food sector. 2. They differentiate themselves primarily through the **creation of new product** varieties. This result holds true for the Netherlands, where this strategy belongs to the three most important ones that entrepreneurs list in the CIS survey. 3. The relocation of production is more of a concern (supply of raw material, distribution) whereas technology driven industries are bound in their location choice by the available human resources (see Peneder 1999). The strength of the Finnish pulp and paper industry union is a result of the latter.

Labour intensive industries are typical for Austria. Her poor R&D performance and low score in patents, is partly due to her specialization in sectors with traditionally low innovations and low propensity to patent. Austria's labour intensive small and medium sized firms need less R&D and patents, explaining why survey data report much higher innovativeness than OECD data. But Austria is, together with Germany, also strong in mainstream manufacturing. Finland's **capital intensive** pulp and paper industry and telecommunication, which is partly found in mainstream manufacturing (electronic equipment) and R&D intensive sectors (new communication technologies), explain its good performance in R&D.

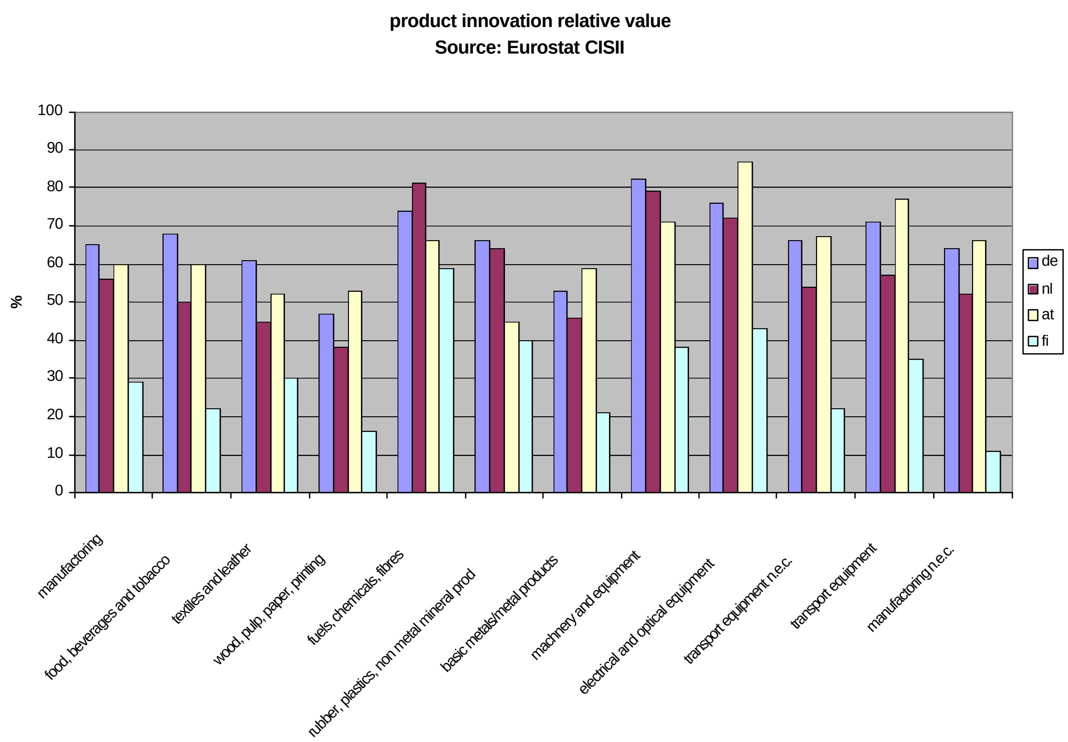
A large part of innovative performance differences, can be explained by sector specialization (see also Polt et al 1999) but not all.

Table 4.8. Country Specialization by Input-factor: Value Added Shares in Total Manufacturing (1997 in %)

Country	**Mainstream manufacturing (1)**	**Labor Intensive (2)**	**Capital Intensive (3)**	**Advertising Intensive (4)**	**R&D Intensive (5)**
Austria	26.39	18.83	16.29	24.61	13.88
Finland	22.82	14.98	28.59	17.54	16.07
Germany	28.06	14.13	15.46	16.22	26.13
Netherlands	21.5	11.75	19.23	31.2	16.37
USA	21.26	12.22	13.51	23.17	29.84

1) includes the machinery sector, articles of paper, plastic products, electronic equipment and motorcycles
2) includes textiles & clothing, wood processing, construction material and metal processing
3) includes pulp & paper, refined petroleum, basic chemicals and iron & steel
4) includes mainly the food sector
5) includes chemicals and biotechnology, new information & communication technologies, and vehicles for transport.
Source: Peneder 1999

Figure 4.3: Product Innovations in % of all Enterprises



4.5.2. Geophysical and Technological Lock -In

From a geophysical perspective one can argue that the German and Austrians specialize in industries related to the mountains such as basic metals, the Finns lived from the products of forests and the Dutch from the water and from trade. Some of the roots of specialization can be traced back to medieval y, others emerged after world war II or changed dramatically since. The German artisan, e.g., goes back to the medieval guild (see Streeck 1987). Also today the Germans are still highly specialized in machinery and artisan products, though there have been major changes in German industrial order (see Herrigel 1998 for the changes in the steel industry since 1970). The Austrian's specialized in tourism profiting from the Alps in the early 1960s. The Finns are leading in paper industry and the Dutch are still experts in water works and trade. Who else but the Dutch would have the skill to put fragile perishable flowers on an international market? It was, hence, to be expected that the Dutch are strong in what Hage and Hollingsworth (1999) call marketing arena innovations, in distribution channels and in logistics.

However, some countries seem more able to escape lock in than others. Though sector specialization is historically grown and highly dependent on the geophysical environment and country size, some countries seem to be more locked in than others. **Finnish big firms seem particularly able to escape from technology lock-in.** Finland switched from the business cycle dependent wood and paper production into mobile telephones in the late 1980s and switched from the declining Russian markets to new markets in China with growth rates of 30%-50% annual in the 1990s (see the Volkskrant 4.6.1999).The Austrians and Germans seem much more stable in their sector development than the Dutch or the Finns. Sector specialization and technology lock-in do not entirely explain why some of our countries are more open to change and to innovativeness than others.

4.6. Some Riddles regarding Performance

To measure sectoral performance in global sectors such as biotech and telecommunications is tricky. The relative poor score of Germany and the impressive patenting activities of the Netherlands give some doubts of what we measured. May be it is just the amount of multinationals and less the performance quality. However one can see that Finland has the highest dynamic, that Austria performs poor with regard to innovations and that Germany is stronger at the begin of the idea innovation chain than at its end. The performance evaluation leaves us with some riddles.

4.6.1. The Austrian Paradox

Each country shows some unconventional performance characteristics. For Austria, the "European paradoxon" (s. Grande 2000 quoted in Martinsen et al 2001) seems to be reversed. Both at the national and at the sectoral level its poor innovativeness is compensated by good economic success. It seems to reap the benefit of others.

4.6.2. The Finnish Capacity to Surpass

For Finland, the most striking result from the data is its capacity to change. The increase in patents between 1975 and 1996 by more than 200%, the fast recovery from the decline of the Soviet Union, the technology intensity make it special. Finland's success is based on very few products, a high specialization and on the success of very few firms.

Finnish survey data indicate less innovativeness than the "objective" data. Here, the bias of the indicators towards technological intensive sectors, which Finland has, might be the explanation for overestimating Finnish innovative success.

In the country ranking Finland comes closest to Austria, which is partly explained by the similar country size of small open economies. In the sector rankings there are however some differences, in particular in telecommunications.

4.6.3. The German Leadership - a Size Effect?

We compared three relatively small countries with one big. Germany is leading in almost all innovativeness indicators, has the largest amount of patents per inhabitant, has the highest R&D expenditures at the national level. What is striking is that Germany is a net technology importer. One would expect a big country to export technology.

As our study will show, size explains why Germany invests more in technology than small countries that can import and diffuse technology. But Germany also has more funding capacity than the other countries. Size does explain part of the German success but not all. Sector specialization, firm size and German institutions also add to the story, as the German report shows. Altogether, Germany ranks top in economic and innovative performance at the national level. However, at the sectoral level its performance is not as impressive as at the national. Why is German telecom and biotech performance according to the traditional indicators poorer than one would expect?

4.6.4. The Dutch - Imitate instead of Innovate?

The Dutch take a lead in subsectors, but overall they rank behind Germany. This is partly again due to the smallness of the country. But the Dutch seem particularly good imitators as expressed by imported R&D. But the Dutch also have found niches where they produce at world market level. The sector comparison reveals that the Dutch do extremely well in both high tech sectors. Where do all these patents come from if they invest less in R&D?

Chapter 5. Organization. The Architecture of the Idea-Innovation Chain

Herman Oosterwijk and Frans van Waarden

5.1. Complexity and Differentiation of the Idea-Innovation Chain

Innovation, according to the OECD's Frascati Manual (1993), involves the transformation of an idea into a marketable product. Sometimes the innovation process is sparked by a major discovery, but it is also a process of just solving problems, of trial and error, in which only a small minority of original *ideas* will eventually make it into an *innovation*: a new product, production process, or a new form of production organization, with commercial value.

In this project we have used the concept of an *idea-innovation chain*. It assumes that, before a new idea can be transformed into a marketable product,, it has to pass several stages of development in a certain sequence of events. The innovation process has often been organised in a linear series of events, especially in Fordist systems of production. Usually this processes started in basic research subsequently moving through the stages of applied research, product development production and marketing, finally reaching the market as a new product or service. A linear representation makes sense at first sight, because finishing one stage is of development is in general a precondition for entering the next stage.

However, this classical linear model of innovation, which had its peak in the post-war decades, is seriously in decline. It was long thought that science was the sole initiator of innovation; an increase in scientific inputs into the pipeline was thought to directly increase the number of innovations and technologies flowing out of the downstream end. But this linear view narrows the input of a certain stage too much to the output of its preceding stage and thus easily neglects important other inputs like learning effect, coping skills and bright ideas developed somewhere along the up- or downstream phases of an innovation trajectory. Furthermore, innovations appear in many forms, from the most radical ones, which outdate existing products and technologies in one blow, to small adaptions of products and incremental improvements to processes (OECD, 1997). Each of these is the result of different innovation processes. They also tend to be interlinked. Often, innovation is an ongoing process of products being modified over and over again, building on valuable insights gained in the up- and downstream phases of the process, with information from each stage moving back- and forth through the distinctive phases. Moreover, innovation is a matter of learning and knowledge generation. Thus, the innovation process has not a clearly delimited sequence and automatic follow-on. This change of thinking is reflected in the different models of the innovation process that have been proposed in the literature.

5.1.1. Linear Models of the Innovation Process

Rothwell (1994, pp. 33-53) has distinguished different versions of the linear model of the innovation process, and he has linked each of these to a different period of economic development since the Second World War. We will discuss these phases briefly, as stylised models.

Period 1: 1950 - mid 1960's: Technology Push

The first period of postwar recovery is characterised by the growth of new technology-based sectors and technology-led regeneration of existing sectors. The importance of research and development were strongly emphasised as an infinite source of ideas, and a range of novel products were brought to the marked and quickly diffused. Demand in this period largely exceeded production capacity.

The dominant model of innovation was the *technology-push model*, which assumed a step-wise progression from scientific discovery, through the phases of applied research, technological development to production, leading to a stream of new products into the marketplace. The idea that science is playing an originating role in industrial innovation has been especially strong in these first post-war years. The experience of the scientific community in World War II was pivotal in establishing the widespread belief that science could make major contributions to industry (Steinmüller, 1994, p. 55).

This model assumes that an innovation process starts in basic research and subsequently passes the stages of applied research, design and engineering, production, marketing, and sales. Each of these functional arenas produces outputs and these are transferred to the next arena as inputs. Thus, basic research outputs, its theories and findings, are used as inputs for applied research. In line with the sequential nature of the model, the flow is unidirectional. The 'downstream' stages of the innovation process do not provide inputs for the earlier stages (ibid. p. 54). This 'logic follow-on' of stages is the more encouraged by a certain similarity between the linear model of innovation and the 'logic follow-on' of a production chain. One can easily draw a parallel set of boxes representing the procurement of raw materials, the processing of materials, product development, production, and the marketing and distribution of final goods (cf. Porter, 1990). However, the technology-push model rests on the premiss that innovation is solely a science-driven process, with basic research as the inexhaustible source of ideas and inventions. This model may have been helpful in explaining the break-through of some major technologies, but the main shortcoming of the model is that it lacks explanatory power for incremental innovations.

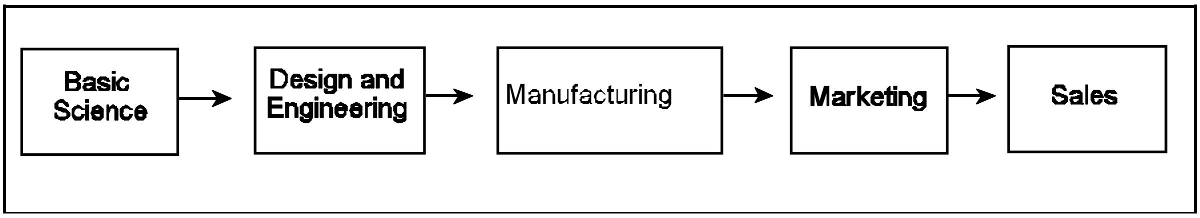


Figure 5.1. Technology Push (1950's - mid 1960's)
Source: Rothwell, 1994

Period 2: mid 1960 -early 1970: Market Pull

The second period that Rothwell has identified is marked by general prosperity, with an emphasis on corporate growth through organic growth, but also through acquisitions and mergers. Capacity and demand were more or less in balance. During the latter part of the period competition was intensifying, with marketing being the strategic activity. The marketplace gained importance in the innovation process. This has led to the emergence of the market-pull model of innovation in which innovations deemed to arise as the result of perceived -and sometimes clearly articulated- customer demand. Here the marketplace was seen as the source of ideas and customer-needs were increasingly directing the moves in research and development, which was thus a more reactive role. This model has had strong implications; science was still an important source of knowledge, but it has lost its predominant prerogative to the market.

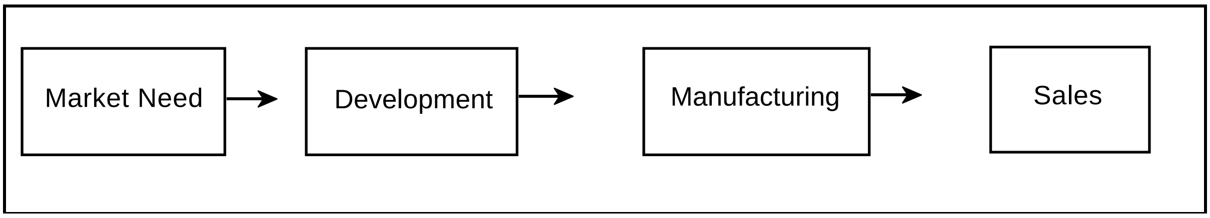


Figure 5.2. Market pull model of innovation (late 1960's - early 1970)
Source: Rothwell, 1994

This model is much better suited to explain incremental innovations. The customer has gained importance in directing innovation activities and the innovations taking place in this period were rather seen as variations on a given theme than as pioneering new technologies. Whereas the technology-push model of innovations has led to subsequent ‘generations of technologies’, the market-pull model has led to gradual change and variations in products (cf. Metze, 1992, 1997).

Period 3: mid 1970's - early 1980's: Interactive or Coupling Model

The 1970's have been a period of high inflation and stagnation. Demand in many technologies was saturated, especially regarding standardised products. The capacity of supply increasingly exceeded demand. Company strategies were oriented toward consolidation and rationalisation. The central strategy was cutting costs. The emphasis in the 1970's models was on the careful balance between science, technology and the marketplace. This has led to the so-called *interactive* or *coupling* models of innovation, which, according to Rothwell and Zegveld, can be regarded as a logical sequential, though not necessarily continuous, process that can be divided into a series of functionally distinct, but interacting and interdependent stages. The overall pattern of the interaction process can be thought of as a complex network of communication paths, both intra- organisational and extra-organisational, linking together the various in-house functions and linking the firm to the broader scientific and technological community and to the marketplace.(Rothwell and Zegveld, 1985, p. 50).

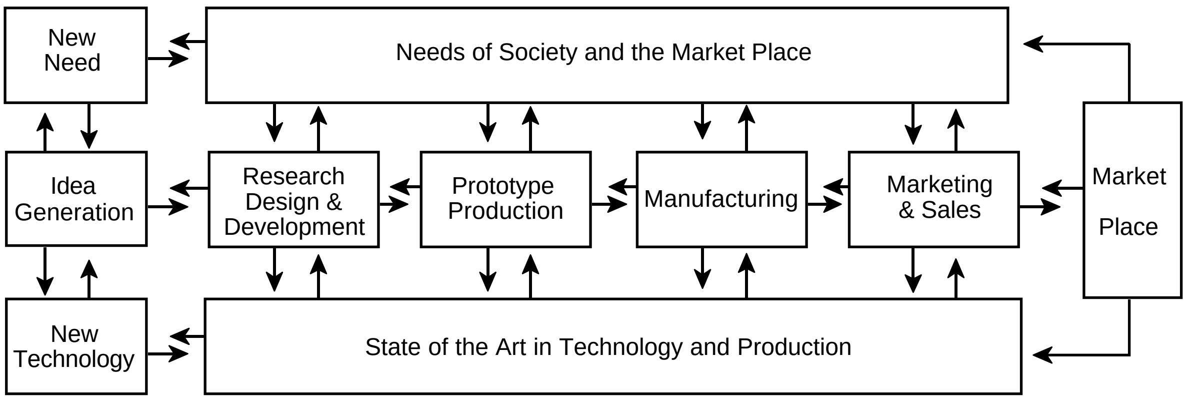


Figure 5.3. Interactive or coupling model of innovation
Source: Rothwell, 1994

Period 4: early 1980s - 1990s: Extension of the Interactive Model

The fourth period started with economical recovery, but was soon followed by recession. Firms increasingly concentrated on their core business and core technologies. This period has been marked by a growing awareness of the strategic importance of emerging generic technologies and with an increased strategic emphasis on technology accumulation and/or manufacturing. Other characteristics have been: a strong growth in the number of strategic alliances, strategic acquisitions and internationalisation of ownership and production; major impacts of new technologies and there has been a high rate of technological change; an emphasis on flexibility, product diversity and quality, and a continued emphasis on technological accumulation; short product life-cycles with growing strategic emphasis on time based-strategies (just in time production and logistics). The dominant innovation model in this period has been a further extension of the interactive and coupling model, especial regarding the changes in the sequence of activities.

The previous technology-push as well as the market-pull models of innovation were basically purely linear models with a predefined flow of knowledge between the components, whereby each stage was building on the inputs of the previous stage. Rothwell's interactive or coupling model has recognised the importance of feed back loops, and the importance of interaction with the firm's environment. Thus the stages of development were no longer solely linear, but had changed into bi-directional flows of knowledge, able to provide inputs to previous stages of development. However, all models remained basically sequential ones. A certain stage would only be started once the previous stage had finished its work, even in the interactive model.

5.1.2. A Circular Model

Sarmento-Coelho (2000) has represented the innovation process as a circular process. She identified the following four phases: *conception*, *invention*, *innovation* and *diffusion*. Each of the phases has a considerable overlap with the next phase and each phase also, covers the activity of several functional arenas with distinct tasks in the process. The start of each phase includes a 'go/no-go' decision.

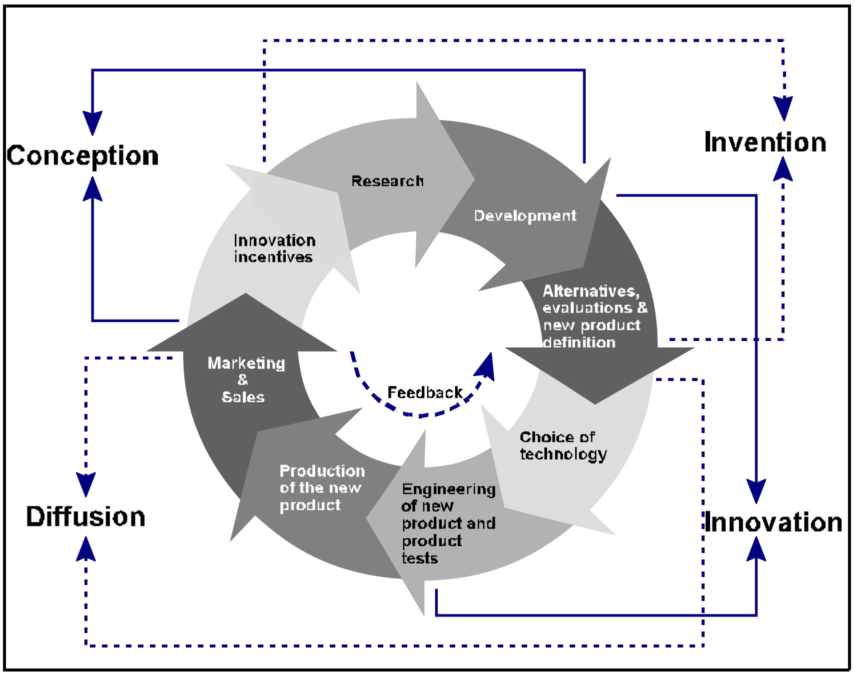


Figure 5.4. The innovation Process and Technology Transfer for the Development of a New product, Good, or Service.
Source: Sarmenta-Coelho, 2000

The *conception phase* starts with the awareness of innovation incentives. It sets the agenda and gives direction to the research process. Promising ideas are researched in this phase and developed into a prototype, which basically covers all the characteristics of the intended product. The *invention* phase, which largely overlaps with the conception phase again includes research and development activities, but it also includes the evaluation of the properties of the intended product and a search for possible alternatives. The principal decision whether or not to bring a product to the market is included in the evaluation of alternatives. The evaluation starts, with what Sarmenta-Coelho has called, the *innovation* phase, that is, bringing an idea with known properties to the market. This includes the choice of technology and the engineering efforts to produce the new product. The *diffusion* phase starts as soon as it is obvious which technology finally will be chosen to manufacture the new product, and all the subsequent steps like product engineering, production and marketing and distribution. What closes the circle is that experience from the market is brought back into the process as an incentive for a new round in the innovation process.

This circular model sees the innovation process as a circular movement, which highlights the importance of feedback processes throughout the system.Yet, it too remains caught within the perspective of the process as a simple sequence of stages, and without any links to the outside world.

5.1.3. The Compression or Parallel Model

The models that Rothwell has identified throughout the postwar period have developed from purely linear, sequential models into two directions. The first direction is represented by the parallel or integrated models of innovation which have especially developed in the Japanese automobile and electronics industry and are variations on the sequential approach, tailored to high-speed, demanding environments. This model assumes that the steps of the innovation process are still well known in advance, but need to be adjusted to gear up with the dynamics of the fast changing environment. The goal is to increase the speed of product development, while maintaining low levels of uncertainty which are inherent to the sequential model. The rationale of this model is to compress previously sequential steps into parallel activities. The advantage of this approach is that the separate phases of the innovation process are better attenuated to each other, and that it has increased the efficiency of time management. Various instruments can be used to compress the innovation process: improving planning, simplifying the process, elimination the unnecessary steps, overlapping steps, and rewarding people for speed of development (Eisenhardt and Tabrizi, 1995). The crucial element in the compression strategy is planning. If pre-development planning is accurate, the entire process can be rationalised, delays eliminated and mistakes avoided (Kamoche and Cunha, 2001, p.740).

These models portray an integrated and parallel process of innovation activities, whereby researchers, managers, engineers and marketeers are all involved in the same innovation project. Core features are a very high level of functional overlap during the process and a high level of integration of the functional members of the innovation process. This model is often compared with the performance of a rugby team, whereby each player, no matter how far away from the ball, anticipates the action to come and already makes his moves in the field. This metaphor, used by Imai, Nonoka and Takeuchi (1985) clearly expresses the joint involvement of all the functional departments in the innovation process.

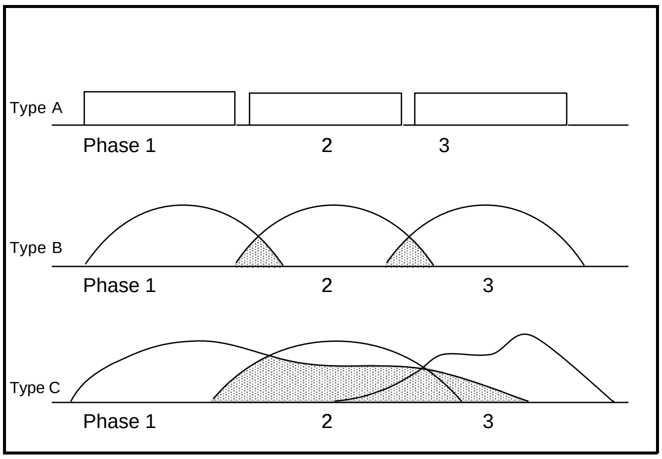


Figure 5.5. Modes of innovation: Type A: sequential, Type B: overlapping, Type C: Integrated
Source: Imai, K. et al., 1985

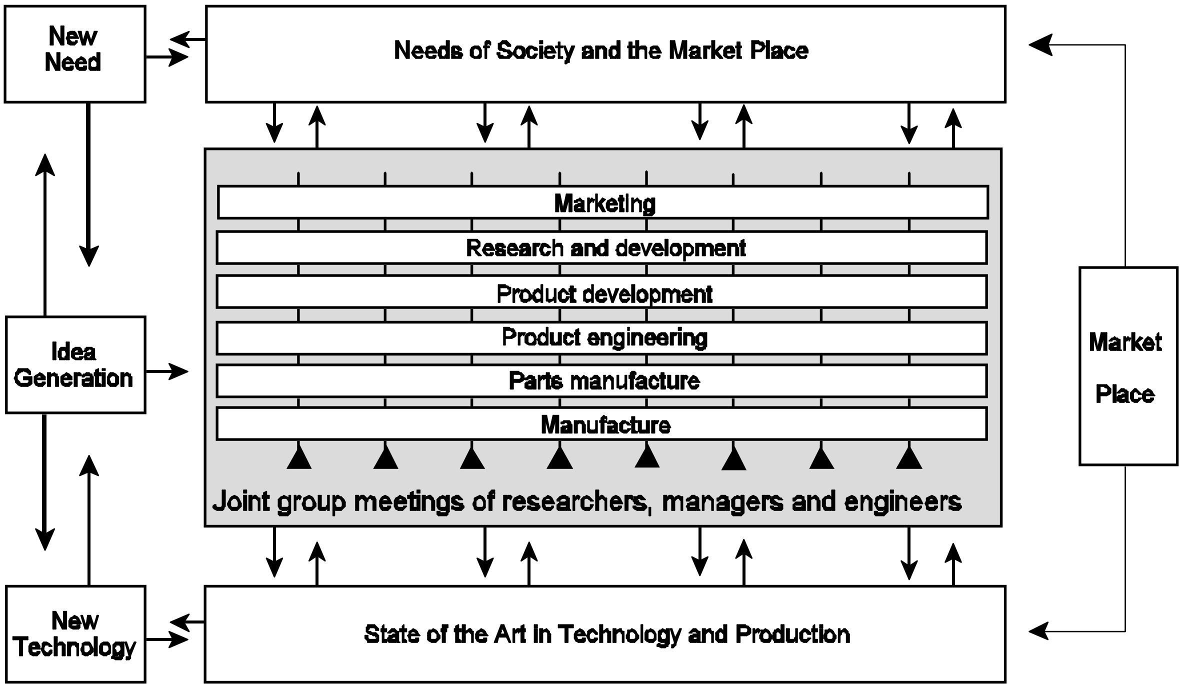


Figure 5.6. An example of a parallel and integrated model of innovation. The setup of research activities in the grey box is basically parallel and highly integrated

Cross-functional (parallel) and more effective integration of innovation activities has yielded a faster development trajectory and has lowered costs. This is explained by the benefits of increasing networking among economic actors. The number of horizontal strategic alliances has increased, especially since the 1980's, and so has the number of co-operations in R&D. But not just horizontal cooperation has increased., but also vertical co-operation, especially on the supplier/producer interface. Innovative SMEs are forging a variety of external relations with both large and small firms (Rothwell, 1991). Leading edge innovators today, are moving towards system integration and networking models of innovation.

5.1.4. The Flexible Model

The second direction in which Rothwell's models developed was towards flexible models of innovation. They have especially developed in turbulent environments with high levels of uncertainty, which demanded radical new perspectives. Flexibility is key in this approach, because it allows high responsiveness to changes in the environment and it has the ability to adapt to emerging opportunities. The flexible model rejects the sequential/mechanistic structure of the innovation process. Uncertainty becomes an opportunity, rather than a tread, which calls for the adaption of flexible/organic models (Thomke and Reinertsen, 1998). Departing from the idea of product development as a rigid sequence of phases, the flexible model proposes the use of rapid and flexible iterations through system specification, detailed component design, and system testing (Iansiti, 1995, p. 2). The model therefore adopts a more dynamic perspective, aiming, nevertheless, to keep the concept development stage as open as possible, in order to avoid launching outdated 'new' products. Flexibility involves the simultaneous resolution of different functions to promote overlapping phases as well as a certain overlapping of concept development and implementation activities, thus achieving convergence (Kamoche and Cunha, 2001, pp. 741-

2).

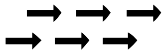
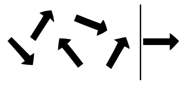
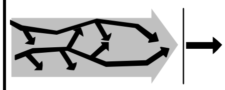
Each of the models discussed so far, had its shortcomings. The main shortcoming of the sequential model of innovation is its rigidity. The sequential model is time consuming and much too formal to allow for deviations, and it is therefore susceptible to glitches. The Achilles' heel of the compression model is that some steps of the innovation process do not get the attention they need and quality may suffer, due to shortcuts in the process. The flexible model of innovation is hard to coordinate. Possible delays in concepts freezing might easily occur and high uncertainty can easily become counterproductive.

5.1.5. The Improvisational Model

Kamoche and Cunha (2001) have proposed yet another model. The metaphor used for this model of innovation is jazz improvisation, not to confuse with ultimate freedom to play::*'You can't improvise on nothin, man; you gotta improvise on something!'* (Charles Mingus, the famous composer and bass-player Mingus cited in Kernfeld, 1995). Within the minimal structures of consensual guidelines and agreements, the members improvise in a creative way to reach large outcomes and effective action. Improvisational freedom is, thus, only possible against the well-defined backdrop of rules and roles.

Trust is an important part of this process, it results from comparable skills among the members as well as from the psychological buffer which helps to prevent from errors, which are inherent to the nature of experiment.Improvisation involves a constant refashioning and re-interpretation of the performance in response to colleagues and audience (Kamoche and Cunha, 2001, pp. 733-764).

Kamoche and Cunha's classification system has integrated these approaches in a sophisticated, but elegant classification system.

Model	***Sequential***	***Compression***	***Flexible***	***Improvisation***
Process flow				
Underlying assumption	Purposive rationality and predictability in stable environments	Activities can be predetermined. Process can be adapted to the environment	Embracing change. Absorbing uncertainty	Action through experimentation. Improvisation is based on a template
Process goals	Achieving efficiency. Reducing uncertainty Providing operational guidelines	Increasing speed while keeping low levels of uncertainty. Efficiency in time management	Achieving flexibility. Responsiveness. Adapting to challenges	Discovery and unrelenting innovation. Balancing between structure and flexibility in dialectical fashion
Process characteristics	Structured, with discrete phases carried out sequentially	Predictable series of discrete steps, compressed or removed as need be	Variation followed by fast convergence. Overlapping procedures	Progressive convergence within minimal structures. Emergence. Incremental evolution of product features
Main shortcomings	Rigid. Too formal. Time-consuming. Causes glitches. Difficult to achieve in reality	Possible omission of important steps. Traps of acceleration. Quality may suffer due to shortcuts	High uncertainty can be counterproductive. Possible delays in concept freezing. Difficult to coordinate	Can be chaotic and ambiguous. Dialectic logic difficult to sustain. Makes a heavy demand on the appropriate culture and HR systems
Descriptive metaphor	Relay-race	Accordion	Rugby	Jazz improvisation

5.1.6. Inter-Organizational Division of Labour and Specialization

Innovation is no longer the isolated prerogative of the R&D department\of one firm, it is rather the result of complex interactions in and between organisations. Departments are cooperating often more with external organizations, such as those of customers or suppliers, rather than with other departments of their own organization. Cooperation is not restricted to private partners. Public research institutes and universities are increasingly involved in research-projects with private partners, each bringing their own background. Especially technological change should be explored within the social fabric in which the innovative activities are actually developed and used (Archibugi and Michie, 1997).

Today, firms rarely innovate in isolation; instead, they generate their knowledge through interactions with a number of other actors. Even the largest and technologically most self sufficient organisations requires knowledge from beyond their boundaries. It follows that innovations do not originate only from individuals or individual organisations, but rather from their, often complex pattern of interactions (Schibany and Polt, 2001). However, mapping these interactions is not easy. Knowledge transfer through co-operation networks can take manifold forms and innovation-related information-flows are of a multifarious nature. Archibugi and Michie have argue that such flows take place *through market and -non market transactions*. A substantial amount of technology and knowledge transfer takes place, because individuals simply learn, imitate, and exchange knowledge while at work. Furthermore, firms use a variety of sources to innovate, thereby using *tangible as well as intangible* assets. A piece of machinery embodies new technology and demands new skills, but a scientific paper may have a similar impact. Both assets are important sources of innovation. Innovative activities include a variety of actors form the *private as well as the public sector*. Universities, research institutes and other government agencies play a crucial role in fostering technological advance, as do profit seeking business firms (Archibugi and Michie, 1997).

5.2. Coordination in the Idea-Innovation Chain

The necessary complement of any differentiation is the subsequent integration and coordination. This is of particular importance in the innovation process, because of the importance of tacit knowledge. The differentiation of stages in the idea-innovation chain and the subsequent specialization of organizations and departments on one of these stages has several disadvantages. A main one is when the stages are too much separated, only the codifiable properties of the project are passed over to the next stage. The implication is that the more tacit elements in the production of knowledge remain hidden. However, innovation is basically the management of knowledge flows from different sources into one project. Different views may generate unexpected ideas and novel combinations and it is stimulating to have a look in each other’s kitchen just to see what’s cooking. Understanding the routines, codes and logic of other partners in an innovation helps to understand one’s fads, fancies and blind spots. It is especially in the cooperation of different groups that the more hidden elements of creativity come to the surface. Close cooperation helps to establish a common cognitive frame, overlapping knowledge structures, a common shared language, and a recognition of each other’s knowledge domains (Hage and Hollingsworth, 2000). This is easier said than done, but once established the shared frame, knowledge base and language allow individuals to exchange and combine aspects of knowledge which are not common among them (Grant, 1996).

5.2.1. Hierarchies

The traditional solution has been to integrate these various stages within one and the same organization. With a stable demand and infrequent changes in technology, it was advantageous for firms to organise production in large, vertically-integrated firms and to reap economies of scale by producing standardised products (Hollingsworth and Boyer, 1997, p. 25).

The sequential model of innovation, as it has been implemented in the hierarchies of the large, vertical integrated firms, has started from the assumption that there is a certain logic in the follow-on of activities, because the major eventualities of the process are predictable. However, the capacity of the large, vertical integrated firm to organise innovative activities has turned out to be limited. Each introduction of a novel product, a new method or the introduction of a new technology requires learning as well as un-learning. In an activity as complicated and unpredictable as innovation, it is misleading to represent innovative activities in large firms as once-for-all decisions. Decisions on the content of strategies and policies are not so easily implemented. In fact, firms develop routines, habits and rules of thumb to help them cope with a murky, messy and ever changing world (Pavitt, 1994, p. 363). Firms have developed firm-specific competencies. Workers in each department have to familiarise themselves with the new technologies and products. To do this, workers find new solutions, cut corners and find shortcuts in the production processes in order to reduce complexity. But in case of change they also have to un-learn routines that have grown on them as a second nature. Thus, the character of the large, vertical integrated firm is at odds with the demand for flexibility and variety.

With the emergence of demand for more product-variations, the purely sequential model turned out to be dysfunctional, because it was a time-consuming method, unable to quickly adjust to customers' demand. The Japanese firms understood this problem well when they sought the solution in a far reaching integration of functional departments. They replaced the sequential mode of innovation by a more synchronised one. The steps of the process were compressed to speed up and geared to each other. Instead of waiting until a product was finished in one department before it was handed over to the next department in line, departments started to synchronise activities. Information about the product was communicated in a much earlier phase, and the next department in line already started its activities, while the previous department had not finished its work. Thus innovation activities of different departments were geared to each other and communication increased through regular meetings, thus providing implicitly establishing several feedback loops in the process. The time to develop an idea into a marketable product was shortened considerably and the process was tailored to meet the demands of higher-speed environments. These organisational innovations together with a close cooperation with producers and suppliers turned out to be very successful. Major industries teamed up with privileged suppliers and innovation was a joint responsibility .

When high-speed environments turned into turbulent environments producers in some areas have teamed up with other firms - sometimes competitors, sometimes firms in complementary industries (Hollingsworth and Boyer, 1997). Nooteboom (1999) has argued that firms had to concentrate on their core competencies to meet the demands of intensified competition, shortening product life-cycles and globalization. Firms must be able to quickly adjust to changing opportunities. Strengthening the core competencies of a firm implies a strengthening of their learning capacity, especially how to coordinate diverse production skills and integrate multiple streams of technologies.

Concentration on core competences implies that one needs to seek partners which supply competencies which do not belong to one's own core, but are needed as complementary to it (Porter and Fuller, 1986). The main advantage of co-operation is that it allows for more flexibility and supports novel combinations. Different partners have different perspectives; they perceive, interpret and evaluate opportunities as well as threats in different ways and have the best capacity for novel combinations. Partnerships can tap into different sources of competence, yield the advantage of economies of scale and enable to the sharing of risks. It is also advantageous to out-source activities, because fixed costs of investments are transformed into variable costs. Especially the emergence of small innovative and entrepreneurial firms has challenged the innovative capacity of the large, vertical integrated firms. The latter type of firm has recognised that the bureaucratic approach could not meet the agility of small entrepreneurial firms. Some of these large firms decided to found their own 'skunkworks'; smaller, highly autonomous departments/plants that worked on specific problems outside central control with the aim of commercialising their solutions.

5.2.2. Networks

Cooperation between economic actors can take many forms. Outsourcing and back to the core-business can force firms or research laboratories to rely again on the *market*, i.e. to maintain in distant relations to other organizations in the idea-innovation chain. The relations are noncommittal in the sense that dissatisfaction leads partners to exit the relation rather than to voice complaints. Such arm’s length relations have various well-known disadvantages: the potential threat of exit, and of opportunism and hold-up problems, makes firms reluctant to invest in the relation, and to exchange tacit knowledge, so essential for innovation.

Hierarchy, integration in a larger company, has been the traditional solution to such problems, but as we have just pointed out, these tend to reduce the flexibility of and diversity within organizations and thus hamper innovation.

An increasingly often chosen solution is to structure inter-firm relations in more or less stable *networks*. Networks can be seen as standing somewhere between markets and hierarchies. Rather than a simple mechanistic connection between the elements, they represent coherence without contract (the market) or command (hierarchy) (Polt, 2001).

Networks distinguish themselves from vertically integrated firms in that they do not have a hierarchic decision- and responsibility structure. They distinguish themselves from markets in that the actors in a network have mutually accepted a basic set of rules that govern behaviour. The actors in the network have found a balance between self interest and a commonly shared set of social obligations, which may mitigate the risks of opportunistic behavior and hold-up problems. Metcalfe (1995) has suggested that networks can be seen as economic clubs acting to internalise the problems of effective knowledge transmission . Kogut (1998) has regarded network capability as a source of value to firms, contributing to learning and knowledge generation. Grandori and Soda (1995) have defined an inter-firm network as the mode of regulating interdependence between firms. Hage and Alter (1997) have added to this definition that networks cannot be dominated by a single organisation that has absolute hierarchical power, it rather must be governed by the collective will of its participants, and it operates through joint decision making, problem solving, and sharing of profits and prestige.

The structure of networks can vary; some are just loosely coupled, while others build on formal contractual agreements (Freeman 1991). Some are just created to solve a single issue and will be dissolved as soon as they have reached a solution, while others are more stable and enduring, gradually becoming a proto-organization. The degree of formalization, juridification, and longevity can vary. There is a range of formal inter-firm coordination systems, such as alliances, networks, joint ventures, or strategic alliances.

Yet, the success of formal networks often depends on the informal networks. The latter usually build on mutually shared interests, and provide a channel for the exchange of tacit knowledge and learning. Networks, especially informal networks, have a high capacity to exchange knowledge in the idea-innovation chain (c.f. also Saxenian 1996, Ebers 1997).

Combining knowledge in novel combinations requires interaction and exchange between knowledge-holders .Today, individual knowledge-sets tend to be so specialised that the required diversity of knowledge for major innovations can only be reached, when two or more experts combine their different knowledge-sets and create a new, partially shared knowledge base (Hämäläinen and Schienstock, 2001, p. 23). This requires a common cognitive framework, shared language, membership of the same community, overlapping knowledge structures, and a meta-level recognition of each other’s knowledge domains (Nahapiet and Ghoshal, 1998; Hage and Hollingsworth, 2000). This recognition of mutual dependency and the potential for synergy provides a network with an identity of its own, which may allow participants to engage in networking on a base of trust, shared visions, reciprocity and mutual adjustment.

Constituting an innovative network is a matter of careful balancing between differences and similarities. An innovative network requires a certain level of variety among the participants, because diversity of knowledge encourages the learning and the innovation process. Too much similarity among the participant does not generate novelty; too many differences discourages the creation of mutual framework, which is a precondition for innovative effectiveness. Building on Granovetter's work on the 'strength of weak ties' (1982), Nooteboom has argued that partners in a networks should on the one hand have sufficient 'cognitive distance' to each other, to be able to generate and capture knowledge that one could not have generated or captured by him/herself. On the other hand, the partners must be sufficient close in cognition and language to enable communication in a meaningful way.Strong ties may be needed when knowledge is tacit, based on enduring and intensive interaction, or when innovation needs to be in tune with other activities. But strong ties may have the disadvantage of generating too little novelty and too much personal interaction, which may be an obstacle to criticism and flexibility. A well-balanced approach requires the right dose of a minimum level of communication and a minimal diversity of knowledge (Nooteboom, 1999; Hollingsworth 2000; Granovetter, 1982).

The main drive towards alliances is the need to cooperate in order to maintain flexibility, core competencies and the incentives that arise from autonomy, while utilising complementary resources for both efficiency and learning (Nooteboom, 1999, p.49).

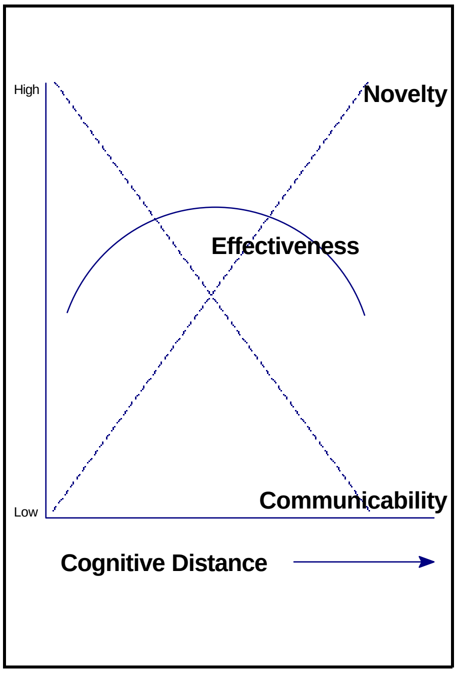


Figure 5.7. Cognitive Distance according to Granovetter 1982

5.3. Architectures of the Idea-Innovation Chain in Biotech and Telecom: the Classic Model before the Paradigm Changes

Traditionally, the idea-innovation chain found in telecommunication and biotechnology was a linear organisation within companies, with only few links to external partners like universities and research institutes. Starting a research project used to be the sole prerogative of the basic research department. If there was any cooperation at this level, it was with universities. One of the oldest telecommunication companies, AT&T, provides us with a good example. Its Bell laboratories have given birth to, or stood at the cradle of, several major inventions in electronics. The transistor, the solar cell and the laser were invented here and the Bell labs contributed considerably to satellite communications, and to the development of digitalisation in telecommunication. The main sources of research and development were concentrated inside the firm. Its organisational setup, size, performance and success has been a benchmark for many industries and most of the European telecommunication companies were organised in similar modes.

The role of universities in general used to be low. In general, the world of science and industry differed too much to allow an easy flow of communication. While the 'world of science' is rather open towards publication of new findings, the ‘world of industry’ is much more carefully. It protects new findings with patents and tries to exploit the commercial benefits of new findings. Yet, good contacts with universities were valued by companies and some, especially the bigger, companies formalised these relations in sponsored professorships. Thus Siemens sponsored chairs at German universities. Some scientific findings were formally transferred to industry through licence-agreements (the arrows in the graph), but there was also considerable transfer in informal contacts. The classical basic research departments used to have an ambivalent orientation; on the one hand research with an economic potential, leading to new products. On the other hand their research had a scientific potential and many scientists moved in scientific circles, which allowed for an easy flow of knowledge.

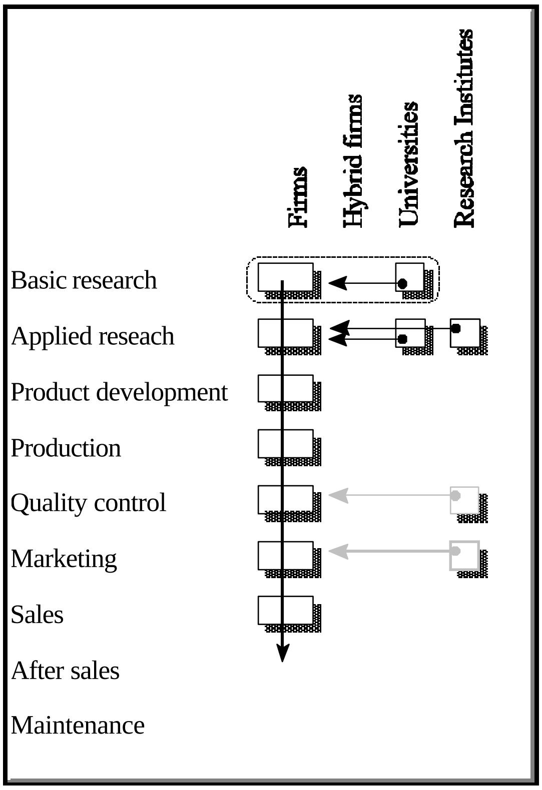


Figure 5.8. The classical idea-innovation chain

The role of research institutes can partly be compared with the role of universities. Especially in Germany the research institutes used to have a strong orientation towards basic research. The Netherlands had a strong tradition in applied research in telecommunication, but also in agriculture and food. PTT’s own research lab was mainly involved in applied research and its findings were -more or less by definition- transferred to industry. The same was true for agricultural research. The public research structure was very strong in transferring its findings to farmers and breeders. Protection of findings was ‘not-done’. The Dutch dairy industry had set up its own research laboratory, which has specialised in lactic acid research. The laboratory was also involved in the downstream phases of the idea-innovation chain, especially in the design of quality control systems. The institute played an important role as a food-information service. It has been a strong promoter of health campaigns. Austria and Finland have set up research institutes relatively late, with Finland being a strong promoter of university-industry cooperation

Relations in the classical idea-innovation chain were basically linear. Knowledge flows were of a sequential mode, with specialised departments performing specific developmental tasks. A project was only transferred to the next stage of development when the department had finished its contribution. A research trajectory usually ended when the product was sold to the customer. After sales and maintenance were not included in the idea innovation chain. This is easy to grasp if we keep in mind that the classical system especially brought forward standardised products for homogeneous markets. This was especially the case in telecommunication equipment. Relations with external suppliers were basically used as external inputs, moving from the knowledge institutes to the companies, thus also adding to the linear setup of the idea innovation chain.

5.4. Changes after the Paradigm Shifts

The architecture of the idea-innovation chains has changed drastically, following the shifts in technological paradigm in our industries. We will describe and analyze the changes in these chains along the dimensions that we distinguished in our research design: (i) complexity, (ii) differentiation, (iii) integration/coordination and their main mechanisms (markets, hierarchies, networks, associations), (iv) a firm´s organizational learning capacity, and (v) the strength of producer-user linkages. These are the structures that provide for different patterns of communication and information exchange as well as for various incentives and disincentives for innovation.

5.4.1. Complexity

The technological paradigm change, particularly in telecom, has increased the complexity of the idea-innovation chain substantially.

a- the diversity of end-of-the-line products (fixed and mobile phones, faxes, computers, etc.) has increased

b- different interlinked systems (voice, data, mobile) have developed

c- as a result, relatively independent sectors have become more interdependent and sector-boundaries are becoming blurred, especially between computer-science, telecommunications, and multi-media. Together, these build new fields of application and provide platforms for further development.

The individual products in the system have become systems in themselves. As compared to the former simple fixed phone, a modern mobile phone is a lot more complex, with a micro-processor, chips, lcd-screen, high capacity batteries, etc. In addition, the hardware system has been overlaid by a software system. The various units of the system are governed by software, that has to be able to communicate with the software of other parts. Furthermore, the technology of the different parts has become more complex: optical switches are more complex than traditional mechanical ones; and so are modern high capacity broadband cables, compared to traditional copper wires, etc.

Software development has become very important, and increased the flexibility of hardware systems contrary to original expectations. Initially, digitalisation was thought to be just another ‘generation’ of switching technology, liable to the ‘law’ of ever increasing development-costs and decreasing life-cycles. In fact, industry looked at digital technology through analogue glasses and did not foresee that digitalisation had a much greater potential and flexibility than ever expected to adjust equipment to changing circumstances. Classical electromechanical telecommunication switching gear had technological limitations; all possible functions (software) were included in its hardware. No functionality could be added after the initial design, without changing it. Was the design of electromechanical switching gear basically one single line of development, digitalisation has differentiated the idea- innovation chain in several parallel chains. In fact, digitalisation has separated machine and function in hardware and software design. To put it simple, a switching system is basically a state of the art computer with a most sophisticated software design to perform the basic functions (switching and accounting), as well as to perform additional tasks (features). The difference with the classical electromechanical switch-boards is that functionality can be added, without changing the initial design.

In biotechnology there is a more or less similar trend, albeit not to the same extent, as this is not (yet) a large technological system. The complexity of the of the idea-innovation chain has increased, especially since the development of methods to modify genes in an organism.

As the diversity of products has increased, so has the variety of scientific and technical knowledge involved in their making: electronics, optics, the characteristics of various materials (metal, glass, rubber, plastics, etc), corrosion, software logic, etc. And as more and more of this knowledge is being privatized, that is, protected by patents, this implies that more and more patents go into the making of a single product. It has been estimated that more than 1000 patent licenses have to be acquired to produce a single mobile phone. In addition to the knowledge required for the products, there is the knowledge needed for an efficient production process, that can produce these parts in large numbers of similar quality at increasingly lower costs.

Each of these parts and processes has its own individual idea-innovation chain - which implies that the overall chain in telecom is made up of thousands of separate idea-innovation chains - both parallel, overlapping, interdependent, and sequential ones. The overall chain is actually more a complex web of idea-innovation chains.

The complexity is further enhanced by the fact that the nature of improvement and innovation of these products and processes differs. The introduction of optical transmission lines and optical switches, or the changeover from electronic to lcd-screens can be considered a radical or strategic innovation; the introduction of the longer-lasting lithium-ion battery in mobile phones is a developmental innovation; and the differentiation of handy's by fashion, looks, and user-groups (the young, frequent travelers, etc) a parametric innovation, to use Whitley's (2000) categories of innovation . These different types of innovations of parts have each their own innovation cycle, duration of development, and product life span. This adds to the already existing complexity of the overall idea-innovation chain.

5.4.2. Differentiation

This increased complexity is only manageable by further differentiation and specialization along the idea-innovation chain. In telecom, the idea-innovation chain has not only differentiated out in separate sub-chains for hardware and software, but also in many for components.

Furthermore, many of these idea-innovation chains have been extended and *new sub-stages* have differentiated out, in particular *in the research phases.* Our original hypothesis (see also. Alter and Hage 1993) that 'high innovative capacity will be related to a greater differentiation in the research links of the idea-innovation chain' seems to get confirmed by the information we have gathered on our sectors.

In basic and applied research in both telecom and biotech the *monitoring* of advances elsewhere in the scientific environment has become so important that it has become almost a separate function. In telecom, hardware production is differentiated in parts manufacturing, final product assembly, and installation - and adaptation to local specifications and circumstances - on location. Software manufacturing has become a continuous process of adaptation and introduction of new service possibilities, in close cooperation with the service providers. Marketing has been extended to the installation and implementation of equipment. After-sales service has become increasingly important. In some cases equipment suppliers provide complete turn key projects to mobile phone operators, complete with financing, and even the actual management and administration of the telecom system. With the service provider being reduced to a mere bill sending firm. Furthermore, the marketing and sales-people have specialised in the definition of customer-demand. and are trained to feed back that information to the research department. Thus, the relation between customer and supplier has changed into an iterative process, whereby information and knowledge is exchanged rapidly to both partners.

In biotech the differentiation has taken place mainly in the research and development stages of the chain. While telecom is an assembly industry, biotech is a process industry. But unlike the bulk chemical industry, actual production in red biotech, is a relatively small scale activity. Pill making and packing does not take extensive production facilities. Though that may not hold for green biotech, even there manufacturing is not such as extensive system of interrelated production facilities as in telecom. In biotech, by far most of the work is done before the production stage. Pharma production can be said to be production of research. It is one of the strongest science-based industries.

Already under the old chemical paradigm of drug development, the road to a new drug has been long (ten to fifteen years) and therefore expensive and filled with risks and uncertainties. It starts with a search for a New Chemical Entity (NCE) that might promise to have medical effects. As soon as such an NCE has been found - on the average 1 success in 100.000 trials - further development follows a rather standardized pattern, with different stages. The so-called pre-clinical research stage consists of testing the new drug in smaller organisms, using cell and tissue techniques. Effectiveness, quality and safety are central in this initial stage. If the new drug yields high promises throughout the preclinical stage, it enters the second stage of a four-step, standardised clinical research programme, in which the drug is tested in humans. The first step (phase I) is research in a small group (50 - 100) of healthy volunteers. Central is the question how humans react to the new drug. Are they tolerant to the drug, and if so, in what doses? Phase II is to test the drug in a group of patients (200 - 400). Is the new drug active and effective in beating the specific disease? The properties of the drug are tested through and through, and experiments are performed to find out the right doses. The third phase is to test the drug in large groups of patients (>1000). In this phase the effectiveness of the drug is compared to the effectiveness of other drugs. Also side effects are studied. The third phase is divided in two more steps. In phase IIIA the drug is not registered and the drug is tested on its effectivity (placebo effects) In phase IIIB the drug is registered and doctors can prescribe the drug to patients. Now the medication is tested for other indications and diseases, and so are side effects. Effectiveness of the drug is central in phase III. In phase IV, which takes place when the new drug is on the market, the effectiveness of the drug is monitored to identify unexpected side effects. The emphasis in phase IV is on safety, extension of the indication area and interaction with other drugs.

The application of biotechnology in drug development promises the possibility of less trial and error and more focused - even on the individual - research. But that is only a long-term perspective, after the functions of many genes have been identified. Until then, the process of linking genes with the production of proteins and certain diseases remains one of trial and error, although the use of biomatics promises to speed up this process. For the time being, it does not like the research process will be shortened. And the anxiety and concern about genetic engineering has so far led only to stricter rules for trials and testing, which are likely to lengthen the testing period further. In green biotech this is even new. One could say that the idea-innovation chain is here extended with sub-phases of field-testing, and the building up of social acceptance.

5.4.3. Specialization and Division of Labor between Organizations

Not only have the stages in the idea-innovation chain become more differentiated. The division of labor of the various functions and stages over organizations has become more complex. Under the old electro-mechanical paradigm, most stages of the idea-innovation chain were located within one or a few large firm hierarchies. Each nation had its own telecom system standards, its own products, and a few suppliers who had privileged access to the market. Siemens in Germany, Philips in the Netherlands, and the KISS-cartel in Austria. Most of these large equipment suppliers did their own research and product development, scanned markets, set their standards, manufactured their products, cared for product quality control, provided after-sales service, trained their own workers, and financed their own projects. Such has been also the case with many of the large pharmaceutical firms.

The paradigm shifts have increased the need for knowledge, and from a variety of sources, thus forcing different industries and firms to combine forces. The dynamics of product development under competition have provided an incentive to do so. Furthermore, in telecom the privatization and liberalization broke up the old duopolistic market structures.

Thus we have seen an increase in the number of firms active in our industries. While firms have withdrawn from the front end of the idea-innovation chain - basic research - leaving this more and more to public research institutes (which however withdraw there too, forced as they are by their public financiers to become more commercial and finance a larger share of their work out of commissions by business firms); we see an increase of the number of different firms and other organizations, active in later stages: in applied research and product development, in engineering, design and consultancy, in manufacturing, and in marketing. These either are specialized on a part or sub-product - and organize a large part of the idea-innovation chain for that product; or, what is more often the case, they are specialized on a specific function within the idea-innovation chain: engineering, design, testing, marketing.

In telecom the process is mostly top-down, with the major players in the industries - Nokia, Siemens, Philips, Ericcson, Alcatel - concentrating more and more on their so-called core competencies, and outsourcing many activities in the idea-innovation chain to a plurality of supply firms. The core competencies are more and more in product development, engineering, design, marketing and brand management, and less in manufacturing. In-house manufacturing gets outsourced; first the accessories and parts, increasingly also whole products, and final assembly work. Outsourcing is also extended to the increasingly important software development. Nokia is now mainly specialized on research, software production, final product design, and brand management. It has largely outsourced actual production. Thirty percent of its employees worldwide work in research.

In biotech the process of increasing division of labor has also come about bottom-up, with small start-ups emerging - in part yet as so-called semi-commercial hybrid organizations - from universities rather than business firms, around embryonic innovations and patents. This process is however also fed top down, as large established players like Bayer have encouraged researchers to start for themselves or have otherwise sponsored small firms in their direct environment. This is certainly related to the fact that the product life cycles, and especially its research and development phases, are much longer in biotech, and that it hence has a much stronger science base, leaving room for specialist organizations in the early phases of the idea-innovation chain. .

5.4.4. Integration

The increasing division of labour in the idea-innovation chain between different organizations raises of course the need for coordination and cooperation. The increasing complexity of products, the need to combine greater variety of ideas, knowledge, skills, implies a greater interrelatedness or interdependence, and where the sub-functions are divided over different organizations, they have to work together: researchers and product developers, developers and designers, producers and customers/users, of parts, semi-finished products, and final consumption products. This is in particular important in custom production, which in telecom usually means the adjustment to local/national specifications and standards, system-characteristics, software, languages, or in the case of business systems to the needs of the particular firm. Much of what the engineers in the telecom equipment supply firms in Austria and the Netherlands do is just this: adjustments of general products to the local market.

This is of course nothing new. In the literature on the economics of innovation, a number of arguments and empirical evidence for the relevance of cooperation among competitors have been provided (Jorde/ Teece 1989; Sydow 1992). We see the need and practices clearly in our industries.

5.4.4.1. Markets

Interdependent organizations in the idea-innovation chain coordinate their activities first of all through the market. Actually, this coordination principle has increased in importance, as knowledge has become more and more a commodity, that is being privatized - i.e. patented - and commercialized. The number of patents has increased dramatically as we have seen and given the interdependence of various forms of knowledge, so has the tendency to license, and with that the flows of traded knowledge. Even formerly non-commercial organizations such as universities and research institutes have *‘learned’* to patent and licence their knowledge to other users. In part they have been forced to do so by the state, who stimulates public research organizations to engage in relations and partnerships with private business by forcing them to earn part of their budget from commissions of business, and who stimulates researchers to start their own little specialized businesses. The latter subsequently have to finance their activities and they do so by selling knowledge.

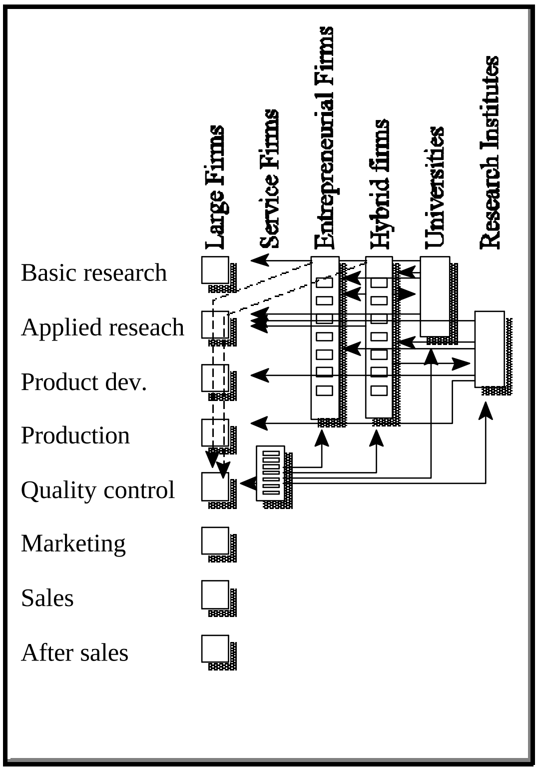


Figure 5.9. Market relations along the idea innovation chain in biotechnology

The importance of market relations differs between different types of firms. They are particularly important between specialized *service organizations* and the *large firms*.

Service oriented business are often rather small (less than 20 employees) and provide highly specialised services. They tend to provide a specific service in a specific phase and are not involved in whatever other phase. In the graph we have placed an example of a service oriented firm as a supplier of service to the phase of quality control, but one can find these type of firms basically at each phase of the idea innovation chain. The relations ae market-like in that the service supplier usually has no other relation to the customer than the service it supplies. The customers of the service oriented firm can practically be any actor in biotech research. Public actors like universities and research institutes are customers, just as well as private actors.

Each service oriented firm has its own idea-innovation chain, but limited to the business. Given the size of the firms, these processes are usually highly integrated in one or a few people. The founder of such a firm is often responsible for the technology, the work-processes, for management and sales. As the firm matures these responsibilities are separated, but usually the firms are such that mutual adjustment is a sufficient method for internal coordination.

It is often though that market relations do not provide much opportunity for knowledge transfer. However, in biotech that is not always whole case. Even though some technologies have been split off from the universities or knowledge institutes in *hybrid* firms, there is still easy access to technology and it is no exception when faculties and hybrid firms are housed in the same building, use the same equipment and employees drink their coffee in the same cafeteria. Also the market relations between *entrepreneurial* firms and large firms provide a good channel for knowledge transfer. That is not so much because of the technologies they supply, but rather in the perspective of their mutual dependence. The entrepreneurial firm is dependent from the large firm for funding and market admission, the large firm in return is depending on the entrepreneurial company because the entrepreneurial firm has the skills and know how to develop new products. Still, market relations do not suffice. Hence they often sooner or later develop into hierarchies or networks.

5.4.4.2. Networks

Within, or in addition to market-relations more stable network relations have developed, both near the end of the idea-innovation chain - in user-producer relations - and near the beginning of the chain - in relations between research and production organizations.

User-producer networks

Intensive user-producer relations have always been a hallmark of the telecom industry, because of the custom-nature of telecom products, and that is still the case. The telecom industry cooperates often closely with the component industries. A usual procedure is that researchers and salespeople from the component industry sit together with the telecom-industry to discuss the basic properties of a new design. The researchers are mainly interested in the technological specifications, while the salespeople have a specific interest in the marketability of a new product. As soon as both parties have agreed about the technological specifications, the research department starts to design a new component specific enough to meet the requirements of the customer, but general enough to be interesting also for other market-parties. Sales and R&D cooperate closely in these processes and as soon as the product is on the market, the salespeople report to the R&D department to adjust and fine-tune the design. In doing so, the linear setup of the idea-innovation chain has changed into a circular setup. People in the downstream end of the chain feed back information to the upstream phases.

Research-production networks

Close network cooperation has also developed between science and industry in the phase of applied research and in the phases of sales, marketing, after sales and maintenance. The basic outline of the current telecommunication system is known to all parties involved and there has been a shift towards applied research. Industry is more and more turning its back on basic research and basic research has mainly concentrated on the area of photonics. Optical transmission, optical memories and optical switching are under construction at universities and graduate schools. It is believed that a system that is fully based on optical technology has a larger capacity and greater efficiency than today's combination of optical and electrical pulses. An implication of this trend is that universities and research institutes have build networks to be active on a horizontal level, that is in joint research with companies, but also in vertical networks, making the first moves in the upstream part of the idea innovation chain. Basic research and its application in demonstrators is so much intertwined in telecommunication that many research efforts are concentrated in these areas.

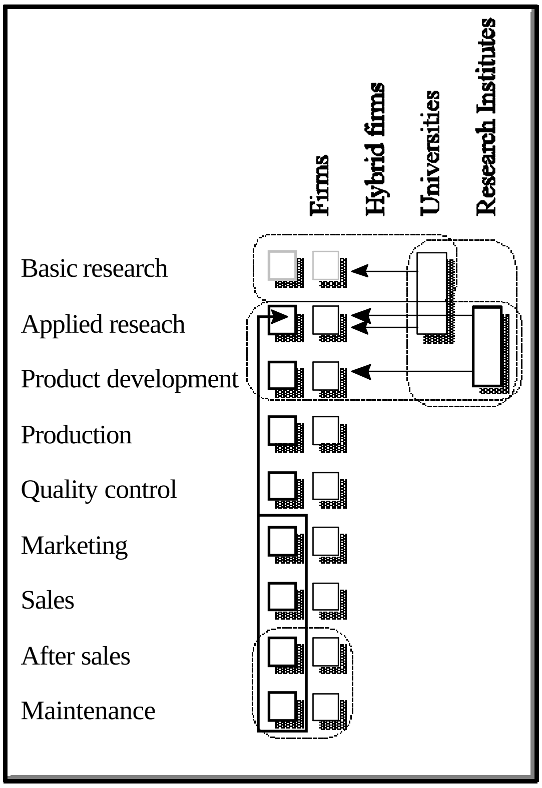


Figure 5.10. Setup of the idea-innovation chain in telecommunication after digitalisation arrows = market relations dotted line = networks

In applied research there is an increasing cooperation between industry, universities, research institutes and relevant others. Here we find several networks concentrating on the main outlines for new products, like for instance video on demand, HDTV, financial services and the like. Partners join each other in pre-competitive research projects for several reasons.

First, these projects serve the purpose of setting out the basic outlines of a technology. Joint research provides a focal point for research and it helps to set the agenda for future research. It narrows and concentrates research efforts of all the partners involves, and thus saves on research costs. This networking in research is beneficial for all partners; it provides them a platform to exchange knowledge. Partners can bring knowledge to, but also take knowledge from the project. Close cooperation in pre-competitive research projects helps to overcome uncertainty as relevant partners commit themselves to these projects. Networking in these networks is intense and aims to develop demonstrators, prototypes, scientific papers and the like.

A plurality of forms of cooperation, both formal and less formal, have been developed and nurtured: joint product development projects, standardization consortia, joint ventures, strategic partnerships, long-term customer-supplier relations, exchanges of staff, knowledge sharing, mutual licensing, associations, and networks based both on bilateral or multilateral contractual relations, or informal connections. Overall, there is a change from hierarchies as mechanisms of coordination to intricately woven networks around the major players in the sectors.

Possibly the closest relations exist between universities and hybrid firms. This is not surprising, as the first form the environment from which the latter have developed. Compared to the service oriented firms the hybrids have better access to technology and technology transfer. Often, the employees work in the same organisational structure, attend the same meetings, use the same equipment, etc. Only their salaries come from different sources. This network evidently allow for easy knowledge transfer.

Country differences in networking

The degree of inter-firm cooperation differs substantially between our four countries. According to data from the Community Innovation Survey (CIS), it is much more common in Finland (78 % of all firms report cooperation with another) and the Netherlands (62%), than in Austria (17%) and Germany (5%) (see chapter by Schienstock on telecom). Furthermore, our country-sector studies report also differences in the mobility of research personnel. This seems to be again relatively high in Finland and the Netherlands, and low in Austria and Germany. Both Finnish and Dutch interviewees report that people in the sector meet often in committees, project groups, seminars; and that after having visited some of them one knows already who is who in the sector. This leads to an accumulation of social capital. Both countries have the advantage of smallness. In the Germanic countries the importance of hierarchy and traditional social distances may form hindrances. And inter-firm collaboration may also be blocked in the Germany by competition policy, which has been much stricter in this country than in the other three.

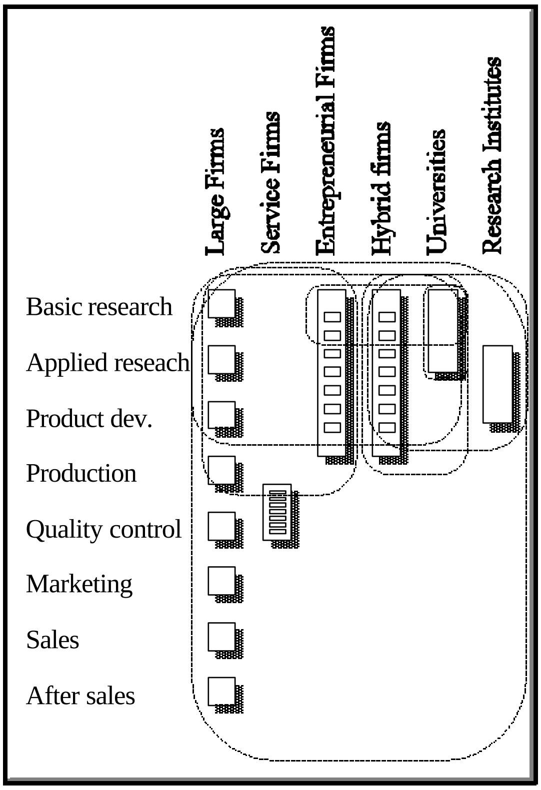


Figure 5.11. Networks along the idea innovation chain in biotechnology

5.4.4.3. Hierarchy

The increased importance of markets and networks should not blind one to the fact that hierarchies continue to play a dominant role in the idea-innovation chains in our industries. Many of the newcomers onto the market or in the networks are sooner or later integrated into larger organizational units.

The already mentioned mutual dependence between small entrepreneurial start-ups and established large firms often becomes cause for replacing markets by hierarchies as principle of coordination. The entrepreneurial firm's scope is usually limited to basic and applied research, and product development. The step towards the next stages is highly dependent on the funds it can generate to bear the costs of market admission. Only a few firms are able to go through these procedures, only relying on their own strength. Usually these firms team up with capital-rich companies in one or another form of strategic alliance or joint venture. More often they are taken over or merge to build critical mass.

It should be noted though that the take-over of a small entrepreneurial firm can be risky for a large company. The main assets of an entrepreneurial firm are its patents and creativity. Patents represent the codified knowledge, but tacit knowledge, which is also an important part of the viability of an entrepreneurial company, is stored in the heads of the people who make the company. Taking over patents is not so difficult, but taking over motivation, creativity and zest is not so easy.

Established hierarchies have tried to combine the advantages of both hierarchy and networks by internal *decentralization* and/or the creation of pseudo-markets and intra-organizational networks. The further differentiation of the idea-innovation chain, and of the specialization of units on it, has had consequences for the internal structure of large firm hierarchies. Central research organizations have been decentralized. Siemens did so and concentrated R and D organizationally in the relevant business unit, and geographically in the region or country where the technology in a certain field is most developed. Thus internet related products in Boston, and mobile internet solutions in Finland (see chapter by Kaiser).

The danger is a centrifugal tendency within the large hierarchy. Several interview partners reported that there was little communication between different divisions and business units of one and the same multinational; and that departments had much closer relations with other firms in their environment, who worked on similar or complementary knowledge or products. This is no surprise to an academic, but typical for specialized experts. Sociologists from one university tend to communicate also more intensely with sociologists from another university, rather than with economists, and not to speak of natural scientists from their own university. In such cases, hierarchies do not function as principles of coordination. There are mere instruments for common ownership and risk spreading for investors, in the end not very different from investment funds. Thus decentralization enhances the formation of *inter*-organizational networks, rather than *intra*-organizational ones.

This puts into question, by the way, the assumption of transaction economics that hierarchies are instruments for coordination and for reduction of transaction costs: if there are no transactions whatsoever between parts of the same hierarchy, then there can also be no transactions costs; and hierarchies cannot 'justify' their existence by reduction of transaction costs if there are none.

Nevertheless, organizations attempt at internal coordination. Just like universities sometimes try to stimulate inter-disciplinary cooperation between different departments. This is most urgent, and also relatively more successful, in firm hierarchies which are relatively specialized on a few products, such as Nokia on the infrastructure and end products of mobile communications. Typical instruments used by Nokia are recruitment of personnel from common pools of graduates that subsequently know each other still from school, mobility of personnel, internal training, and reducing distances through virtual email communities, coffee rooms and idea boxes on the intra-net, which should give larger organizations characteristics of smaller ones. Its managers probably know from the literature that these are supposed to increase the learning capacity of firms.

Chapter 6. Organization: Regional Clustering

Robert Kaiser

For some time now, socio-economic research on innovation has stressed the importance of regions as drivers for economic development within the context of globalized markets and technologies. In view of their innovativeness and their technological capabilities, however, regions can differ significantly even within the same country. As the example of two leading local industrial systems in the United States shows, regions do not only develop different patterns of specialization, they also create different forms of coordination among various organizations. Whereas, in the Silicon Valley, a regional network-based industrial system has emerged that supports collective learning and flexible adjustment among specialist producers, the Boston area ("Route 128") is still dominated by relatively integrated companies in which corporate hierarchies survived and knowledge flows are still organized primarily vertically (Saxenian 1999: 2-3).

Different analytical concepts have been developed in order to evaluate the importance of spatial proximity for the innovation performance of corporate actors and research organizations. What these concepts have in common is their systemic approach towards technological development and innovation. Recognizing that the "regional level economic co-ordination has an important role to play as a functional correlate to the increasing power of globalization as a general economic force", one of these concepts has identified *Regional Innovation Systems* (RIS) as "meso-level entities operating, in political and administrative terms, between local and national governments" (Cooke/Boekholt/Tödtling 2000: 2). However, even protagonists of the RIS concept have to admit that regional innovation systems do not necessarily comprise all elements and functions which are part of a *National Innovation System.* Consequently, there is much evidence that the growing importance of economic coordination at the regional level is caused primarily by a re-configuration of the National Innovation System, rather than an indication for the existence of fully-developed innovation systems at the regional level. In a geographical perspective, many traditional functions of the *National Innovation System* are transferred either to the local/regional or to the European/international level and they are also complemented by initiatives above and below the national level (Kaiser/Prange 2001: 316 f.). A second analytical concept, which in many ways supports the idea of a re-configuration of National Innovation Systems, is the cluster approach.

6.1. The Cluster Approach

Clusters can be described as groups of innovative enterprises, academic and research institutions, local development agencies and other supporting institutions. Thus they combine industry, government and non-governmental organizations, together with a number of knowledge specific players, such as universities, research institutes, management consultancies, patent lawyers, etc. (European Commission 2001). Clusters usually exist as cross-sectoral networks which contain dissimilar and complementary firms specialized around a knowledge base in the value chain. Depending on the technology concerned, such value chains can differ considerably in view of their length. Value chains in biotechnology, for example, tend to be relatively short as they rely almost exclusively on laboratory-based research. In mature clusters with relatively stable technologies, the value chain can be expected to be longer and actors rely more heavily on exogenous sources of knowledge (Bergman/Charles/den Hertog 2001: 10). However, rapid technological change can shorten the length of value chains even in traditional industries, as it has been the case in the telecommunications sector.

The cluster approach can be applied at different levels of analysis. At the macro-level, the focus is on industrial relations and the patterns of specialization in the whole national or regional economy. At the meso-level, analyses concentrate on inter- and intra-industry linkages in different stages of the production chain. At the micro- or firm-level, cluster analysis will focus on inter-firm linkages between specialized suppliers and one or more core companies. As an alternative to the traditional sectoral approach, clusters consist of actors with different network positions and they include customers, suppliers, service providers and specialized institutions. In contrast to that, the sectoral approach has a focus on firms with similar network positions. They are mostly engaged in end-product industries and they are thus direct or indirect competitors (Roelandt/den Hertog 1999a: 13).

Because of the dynamics, systems characteristics and interdependencies which are similar to those existing in National Innovation Systems, regional clusters can be also considered as reduced-scale national innovation systems. As a consequence, cluster-oriented public policies have to be coordinated vertically, involving policy actors at different levels of governance, and horizontally, including various innovation and non-innovation policies. Cluster-oriented public policy is therefore not a new or separate type of policy, but an integrated and general approach, which requires interdepartmental coordination (Roelandt/den Hertog 1999b: 413-414).

6.2. Cluster-oriented Public Policy Initiatives

Public policy initiatives for the establishment of high-technology industry clusters comprise a set of policy activities which are aimed at stimulating the emergence of networks, strengthening inter-linkages between different actors in these networks, and increasing the value added of their actions (Boekholt/Thuriaux 1999: 381): The research project identified such cluster-oriented public policy initiatives in all countries and in both sectors concerned. Most of these initiatives were taken in order to establish or strengthen innovative clusters at the regional level.

In Germany, for example, the federal government initiated a regional competition, the so-called *BioRegio* program, in 1995 in order to stimulate the creation of biotechnology clusters, and thereby the commercialization of scientific knowledge in this field. The *Federal Ministry of Education and Research* (BMBF), which was responsible for the program, designed the competition in a way which clearly favored locations where the infrastructure was already developed. The political intention behind this strategy was to further strengthen already strong and established locations. As a result, the three winners of the competition – the bioregions around Cologne ("BioRegio Rheinland"), Heidelberg ("BioRegio Rhein-Neckar-Dreieck") and Munich – were already favored in the 1980s through the establishment of the national centers for genetical research. A special award was given to the bioregion Jena, the leading location in the new federal states. The *BMBF* supported 57 R&D projects within the four regions between 1996 and 2000 and invested a total of DM 141 million.

The definition of the criteria for the selection of the most promising regions for the commercialization of biotechnology in Germany clearly originated from a cluster-based public policy approach. The participating regions had to demonstrate the interaction of different branches of biotechnology research, the existence of supporting service facilities, a regional concept to support biotechnology start-up companies, the provision of financial resources through banks and public equity capital providers, a working structure for the cooperation between regional biotech research institutes and clinical facilities in the region as well as the capacity of local authorities to effectively decide on applications for biotechnology facilities and field trials (Dohse 2000: 1113).

In many respects, regional public policy initiatives taken by the Government of the state of Bavaria positively influenced the development of the Munich biotechnology cluster which has emerged since the mid 1990s. Firstly, the Bavarian government participated – earlier than other states – in federal-state consultations which took place in order to prepare the *BioRegio* contest. These consultations led to the agreement to strengthen already well-developed locations and to invest only a "symbolic" amount of public money. The basic idea of the program had been to make clear that public policy was ready to support biotechnological research and to improve the conditions for biotechnology companies. At the same time, the Bavarian government started initiatives that were aimed at upgrading the research infrastructure and the provision of risk capital at the regional level. It invested a considerable amount of money gained from the privatization of its share in the former utility and energy company *VIAG AG* in venture capital funds, provided by the newly established state-agency *Bayern Kapital*, as well as in the expansion of the university infrastructure (Kaiser 2001; Kaiser/Grande 2001).

In Austria, the City of Vienna has tried to copy the success of the Munich biotech cluster since the late 1990s. In contrast to the German case, however, the initiative was considerably less funded and introduced at a smaller scale. Support from the federal level did not exist as in the German case. Moreover, research organizations, such as the Max-Planck-Organization and especially its institutes in the Munich biotechnology cluster, which were mainly responsible for the commercialization of biotechnology out of the academic sphere, are of smaller importance in Austria, where basic research is mostly conducted within universities. As a result, the number of biotechnology start-up companies in Vienna is significantly lower than in Munich. Until 2001, the Munich cluster for pharmaceutical biotechnology consists of more than 50 companies, about 5-7 exist in the Vienna Bio Center (Unger/Oosterwijk/Rossak 2001: 59).

The two basic elements of the German *BioRegio* program, the support of already established regions and the provision of public funds on the basis of regional competition, can also be found in a Finnish policy initiative. In the mid-1990s, the *Finnish Ministry of the Interior* launched the *National Centers of Expertise Program* which focused on the further development of already existing high-technology areas. As in the German case, an important goal of the program has been and still is to improve network building among firms, universities, research organizations, polytechnics, training institutions and regional authorities. The ultimate goal of the program is to create specialized regional agglomerations which include globally acting high-technology companies, highly-specialized supplier firms, a local labor market, and a cultural and institutional infrastructure that supports the creation of trust-based relations among the various actors.

The Centers of Expertise have been selected both in view of the quality of research and education as well as with regard to their networking capacity with local firms and supporting institutions. Until 1998, the Finnish government invested a total of **i** 320 million, 290 new high-technology companies have been established around the Centers of Expertise and about 8,000 new jobs were created. (Schienstock/Hokanen/Lyytinen/Tulkki 2001: 101 ff.). Centers for Expertise have been established both in the fields of telecommunications and biotechnology. In biotechnology, the Ministry of Education launched an initiative in 1987 which was aimed at the creation of four Centers of Expertise until 1992. These centers were located in the neighborhood of universities which were regarded as having the capacity and resources to develop a new field of technology. As the examples of Germany and Finland show, regional or local biotechnology cluster tend to organize around their basic thematic focus. Whereas two different cluster for pharmaceutical and agro-biotechnology are under development around Munich, there is a similar division of labor between biotechnology clusters in Finland. The four bio centers in Oulu, Turku, Tampere, and Kuopio are focused on pharmaceutical biotechnology, whereas the centers in Helsinki and Seinäjoki concentrate on agro-biotechnology (Kaiser/Grande 2001; Tulkki/Järvensivu/Lyytinen 2001: 71 ff.).

In the Netherlands, the Ministry of Economical Affairs adopted a cluster approach already in the early 1990s. Regional clusters exist today in the Netherlands both in the biotechnology and the telecommunications industry. As the example of telecommunications shows, well-developed clusters are not only important for the creation of innovative start-up companies, they also attract foreign R&D funds. Lucent Technologies, for instance, established its Dutch research institute within the ICT cluster in Twente where a number of telecommunications and ICT companies as well as public research organizations and a technical university are located (Oosterwijk 2001: 55).

6.3. The Dynamic in Cluster Development

At least in view of the field of biotechnology, it is widely accepted that regional clusters develop in typical phases from the set-up stage, in which publicly funded basic research dominates, to the grown-up stage, in which privately held biotech companies offer established products and are able to finance in-house drug development programs out of internal cash-flow (cf. BCG 2001: 21 ff.). The status of development of a biotechnology cluster can be assessed by various indicators such as the number of scientific working groups, the number of employees in small and medium-sized companies, the number of product candidates, or the amount of revenues originating from services, contract research and product sales. In view of scientific working groups, for example, the Munich biotech cluster has about 320 and other German cluster between 250 (Berlin/Brandenburg) and 380 (Rhineland). In comparison to that, more than 1,200 have been established in the Boston area. The average number of employees in small and medium-sized biotech companies amounts to 20 to 40 in German biotech clusters, while companies located in Boston or the Bay Area have about 90 to 130. The Munich cluster consists of 19 drug developing companies and 50 firms which are specialized in platform technologies, whereas in the Boston area about 80 companies are engaged in drug development and 120 in platform technologies. Revenues of biotech firms are comparable between biotech clusters in Germany and the UK, however, they are three to four times higher in the Boston or the Bay Area. (BCG 2001: 23 ff.).

Cluster-based public policies have to adjust measures in accordance with the development of each individual cluster, since different requirements arise in different phases of growth. In view of the development of Germany's biotech clusters, regulatory measures as well as the provision of venture capital was especially crucial in the set-up phase in which researchers had to be attracted to commercialize their scientific know-how. If a cluster enters a phase of consolidation, as it is the case in the Munich pharmaceutical biotechnology cluster, public policies have to ensure that this consolidation is accompanied by internal growth of the already established companies. Such a strategy requires comparatively strong performance in five fields: competitive research in universities and non-university research organizations, established and working procedures for technology transfer, the availability of capital, the existence of infrastructure especially for commercial activities (i.e. laboratory space etc.), and a sufficient supply of qualified employees. Many of this conditions for success require activities by the state. However, in view of biotechnology of most importance still is the provision of an adequate infrastructure for publicly funded research as it is a precondition for commercialization of scientific knowledge and the development of a biotech cluster. This holds true especially with regard to the creation of a common knowledge base within a cluster. In case of biotechnology as a interdisciplinary field, clusters are in need of certain core competencies which have to be available within a cluster as a precondition for dynamic growth. In case that private biotechnology firms are not engaged in all of these core competencies, knowledge can be provided within the cluster only by universities and non-university research organizations. As the example of the Munich pharmaceutical biotechnology cluster shows, core competencies exist in at least eight segments of pharmaceutical biotechnology. The largest number of actors is engaged in genomics and proteomics as well as drug and gene delivery. Only few actors are working on 3-D structure analysis and new materials. However, it can be said that a critical mass of private actors exist in most business areas, while universities or non-university research organizations are active in all segments (Kaiser/Grande 2001: 94 ff.). The public R&D infrastructure is thus prepared not only to compensate for knowledge which is not or only limited available in the private sector industry. It also provide a basis for further commercialization of scientific knowledge in new emerging fields of technology.

Chapter 7. Institutions Supporting or Hampering Innovation

Brigitte Unger

Firms' activities are embedded in a variety of institutions that may facilitate or hamper innovative and economic performance. The most important institutions are *economic institutions* and *law* and the *legal system*. Laws and regulations, which can for example forbid some activities, such as field trials for genetically modified food (Austria in 1997), influence innovative activity quite directly and intensely. Licensing practices also differ between countries. European directives are not handled the same way in all countries. The national license for a product you should get within 60 days (EU). But some nations do not follow EU rules. Some take a year (like Germany, Interview Baxter). In Austria the license, e.g. to sell a product, is granted relatively slowly, though recent reforms in bureaucracy have improved the situation. Licensing practices are also a big handicap of Europe vis a vis the US. A license from the FDA is valid for the whole US. In Europe a license by mutual recognition must pass all the national licensing procedures in addition. A cumbersome bureaucracy in law implementation can hinder innovations. Among *economic institutions,* the literature on national systems of innovation distinguishes:

1. *Public policy* that can put more or less emphasis on specific sectors by means of innovation and technology policy (see Chapter 8), that can invest into R&D, that can provide subsidies, and that can regulate financial markets and education.
2. The *educational system* that helps to provide researchers, technical engineers and skilled labour, that can increase the flexibility or creativity of workers, the capacity to cooperate etc.
3. The *financial system* that allows to finance more or less risky investments through banks and capital markets.
4. *Intermediating institutions and organizations*, that try to connect firms with other firms and research centers. They have become increasingly important, but have already been discussed in chapters 3, 5 and 6.

7.1. Public Policy Support for R&D

Our four countries differ quite substantially with regard to government funding. The two smallest countries, Austria and Finland have chosen opposite routes. When corrected for country size, Finland is leading in public support for R&D at a national level as well as in the two high tech sectors telecommunications and biotechnology. Government budget appropriations for R&D in % of GDP was 0.95% in Finland, followed by Germany (0.9%) and the Netherlands (0.8%).The huge Finnish public pump for high tech is missing in Austria, which lies at the other extreme (0.65%). Big differences can be found in the focus of public support on biotechnology, which is highest in Finland (8.1 % of all government R&D spending) followed closely by Germany (6.7%). The Netherlands (2.5%) and Austria (1.5%) are putting less emphasis on government promotion of this sector, though the former is more active in particular in green biotechnology than the latter. In Austria, the public support for

R&D and high tech always was and still is very limited, public programs focus on traditional fields of science such as natural science, human medicine, chemicals. The two science based industries, telecommunications and biotechnology, were never at the heart of Austrian research and technology policy. This distinguishes Austria from Finland, also a small country, which has put so much effort into developing these two sectors. National support program in most cases also lack the linking to industrial relevance and application. The share of public support for industrial research is negligible, the biggest share is spent on basic research at universities without any strategic application. Especially small businesses are likely to suffer from this structure because they do not have the lobby to shop for subsidies. There are big efforts made, to improve this situation, lately. But big funds are missing. Public research centers such as the Austrian Seibersdorf or Johanneum cannot compete with the highly funded German Fraunhofer Institute.

In Finland and Germany not only government support in % of GDP is higher, but private investors play an even larger role. This explains why the proportion of R&D that the government finances is larger in Austria (47% of GERD in 1998) and the Netherlands (41%), than in Germany (34%) and Finland (35%) (see Research and Development: Annual Statistics 1998, Eurostat Series 9A).

Table 7.1. Public Funding of Research and Development

		Biotechnology R&D	Total Govt Budget Outlays for R&D (GBOARD)	R&D biotech in % of total R&D
		Million PPP$		Percent
Australia	1998	196.3	2 532.5	7.8
Austria	1997	16.8	1 146.5	1.5
Belgium	1997	181.7	1 314.0	13.8
Canada	1997	261.4	2 581.0	10.1
Czech R.	1999	7.8	749.1	1
Denmark	1997	45.2	945.6	4.8
Finland	1997	94.5	1 165.0	8.1
France	1997	560.0	12 683.1	4.4
Germany	1997	1 048.2	15 595.7	6.7
Greece	1997	6.5	430.9	1.5
Iceland	1997	0.9	68.5	1.3
Ireland	1997	15.0	229.9	6.5
Italy	1997	32.1	7 329.6	0.4
Netherl.	1997	78.0	3 069.9	2.5
Norway[1]	1997	26.8 - 32.2	880.3	3 - 3.7
Portugal	1997	19.2	781.9	2.5
Spain	1997	15.5	3 202.6	0.5
Sweden[2]	1997	65.6	1 795.2	3.7
Switzerl[2]	1997	16.4	1 379.7	1.2
UK	1997	705.1	9 055.7	7.8

1) These data are national estimates, hence the range.2) GBOARD has been estimated.
Source: OECD, based on data from the European Commission (*Inventory of Public Biotechnology R&D Programmes in Europe*, 2000), Eurostat, Statistics Canada, and national sources.

Another characteristic is that the Netherlands depends much more on the financing of R&D from abroad than the three other countries. In the Netherlands 7.6% of R&D

expenditures is financed from abroad, as compared with 4.5% in Finland, 4% in Austria and 1.8% in Germany:

To put it shortly, when corrected for size, public funding supports innovative activity more in Finland and Germany than in the Netherlands and Austria. For a comparison of technology policy see Chapter 8.

7.2. Education

Firms can be more innovative if they have higher qualified personnel. The educational and vocational training system influences the skills of labor and the involvement of workers in innovative strategies (Whitley 2000). Schools, and in particular the existence and quality of polytechnic schools, and technical universities account for the provision of human capital that can be absorbed by high tech firms. In addition, internal training, increases labour skills.

Countries differ substantially in these systems. In countries with more stable employment relations. workers stay longer in firms and ‘voice’ complaints, rather than exit to another employer. The employer does the same: he voices any complaints rather than firing workers. In part this is the result of statutory job protection and strong unions, but it is also a matter of culture. In such “voice” systems employers are more likely to invest in training of their workers, as the chance that a competitor will poach them is less. By contrast, in exit organized systems employers are less likely to invest in their workers as poaching problems are greater; and paradoxically in such systems with a greater need for training as a collective good, there are less of such facilities, due to the weaker associational governance in these countries. It may be that this dichotomy is somewhat oversimplified, as Crouch, Finegold and Sako (1999, p.85-87) stress. They found differences among the exit countries US and UK, as well as the continental European voice countries.

The educational systems are in principal similar between our four countries, that are all corporate associational governance countries, but differ in degree. Corporatist countries in Europe are characterized by well developed vocational training systems organized by the social partners, which combine theoretical training in school with practical on the job training. Typical is the German and Austrian ‘dual’ vocational training system organized by the Chambers (Streeck et al. 1987). They are responsible for the entire training program and content, the duration of training, the syllabi, the inspection, and the certification (Crouch, Finegold, Sako 1999, p.140). The German and Austrian dual vocational training system produces a high level of training for medium skilled workers. The Dutch also have a dual vocational training system but not as tightly organized. Finland has only 5% of workers in a vocational training system (Schienstock 1999). However, the Finish school-based system provides a high level of general skills for its whole population.

Corporatist countries have also well developed public educational systems. Schools are free in all four countries. Universities are free in Germany and Finland, and have only small fees (about 1,800 US dollars) in the Netherlands and in Austria (800 US dollars). All four countries have, hence, a strong public educational system. Finland has a highly decentralized university system with 20 universities for 5 million of population. This is much higher than in the other countries, where one finds about one university per million of inhabitants. But one has to take into account that many of these universities are polytechnic schools, which provide engineers for the telecommunications sector. As our Finnish country study showed, when needed, a local school is transformed in a quite flexible way, into a polytechnic university, in order to provide the necessary degrees.

The OECD (1996) showed that ‘exit’ organized countries (in particular the US and the UK) have a much more polarized labor force in terms of skills. At the high end there are a number of employees who perform highly skilled jobs, and for whom employers are willing to provide job security and investment in training. At the other end of the scale are a large number of low-skilled workers that can be easily hired and fired. As a result, the US has a relatively low share of skilled white and blue collared workers: 37.4% (OECD 1998). This contrasts markedly with our four countries: 58% for Germany and the Netherlands, and 54% for Austria and Finland. That is, the four voice countries vary only slightly in the degree of training and skills. Notwithstanding, sectoral differences in education, and particular for high tech sectors, can be noticed.

7.2.1. Education and Employment in Biotechnology

Modern biotechnology relies much on formal education, as knowledge in this field is highly codified (see Lundvall 1999 and OECD 1006, p.12-15 and our Finnish biotech Report March 2001, p. 77). The knowledge basis of modern biotechnology is highly scientific by its nature.

Biotechnology needs on the one hand computer experts in fields such as bio-informatics. This field has extended the volume and accessibility of huge databases. Computers can process huge amounts of information and high powered computers can perform analysis in a fraction of the time that was needed several years ago. Employability of workers demands high standards of learning, flexibility and the willingness of life-long learning. On the other hand biotech researchers come from medicine, technical and natural science: biochemistry, biotechnology, botany, chemistry, nutrition sciences, genetics, human biology, food technology, medicine, microbiology, molecular biology, technical chemistry, veterinary medicine and zoology can all be related to biotechnology. Countries, who have a tradition of good education in this field, have a comparative advantage.

With regard to R&D personnel per 1000 members of the labour force, Finland is indeed leading, having twice as many researchers per 1000 workers (13.3) than Austria (6.6). Germany (11.7) and the Netherlands (10.5) fit in between these extremes (see OECD, 1998). Finland has invested a lot in education in the field of biotechnology in the last 15 years. Bio-engineers have been educated since the mid 1980s. In 1998 a special master's program was established at the University of Turku. Students are trained either in pharmaceuticals or in food industries, get also an entrepreneur management training and do a part of their master thesis in biotech companies or laboratories. Similar to telecommunication, the Finnish education system seems quite flexible, adapts to new needs. Lack of biotech personnel is and was a hampering fact for the development of the biotechnology sector. The Finns react with offering new education patterns. For example, even polytechnics start offering biotechnology education, though the number of students is still very small (about 1 percent of total student places, who are mainly in telecommunications). More biotech students can be found in pharmaceuticals, in the medical faculties.

The 14 graduate schools that have been established at Finnish universities in order to support research in biotechnology, are mainly integrated in regional biotechnology centers of expertise. Most of the graduate schools are working in the areas of red biotechnology. Nevertheless, lack of personnel stays one major hampering fact in Finnish biotechnology. Finland "borrows" biotech experts mainly from the US.

In Finland, most companies are in the field of diagnostics (27%) followed closely by pharmaceuticals (18%). The reverse is true for turnover, where pharmaceuticals accounts for half and diagnostics for less than a quarter. Food and feed ranks third (19%). There were 8200 people employed in biotechnology in 1999. Not including big pharmaceutical companies, which account for half of the personnel in the sector, there were about 4000 employees in biotechnology. Half of them in diagnostics (51%) and 28% in green biotech. Data do not tell us how many of them were in R&D, therefore, the Finnish numbers are higher than the Dutch.

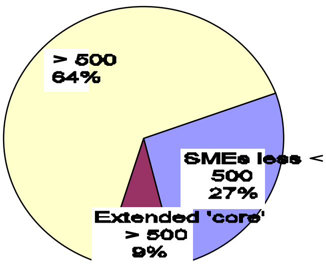
Table 7.2. Finnish biotechnology firms by sector and size class: distribution in 1998 and 1999

	Number of companies		Turnover in million PPP$		Personnel	
	1998	1999	1998	1999	1998	1999
Pharmaceuticals	17	19	714.1	641.6	2 640	4 430
SMEs	14	16	8.3	15.6	140	220
Large pharmaceutical	3	3	705.8	626.0	2 500	4 210
Diagnostics	28	29	201.5	293.4	1 390	2 050
Biomaterials	8	8	7.8	19.6	60	90
Food and feed	10	17	233.6	254.3	1 060	1 050
Industrial enzymes	3	3	53.5	66.5	290	270
Agro	7	7	1.7	13.7	30	130
Service companies	16	19	11.7	11.7	110	110
Other	3	8	5.8	11.7	30	70
Total	92	110	1 229.7	1 312.6	5 610	8 200
Total excluding large pharmaceutical firms	89	107	523.9	686.6	3 110	3 990

Source: Based on data from Finnish Bio-industries (http://www.finbio.net)
Type of biotechnology employment, distribution of 3,990 employees, 1999 (excludes large pharma)

Compared by the number of R&D personnel, Germany is leading. In biotechnology there were about 16.000 people employed in R&D. in 1999 (see graph). Mainly in big companies of the pharmaceutical industry, as the data show, whereas about one third (27%) of R&D employees worked in companies with less than 500 employees. This can still be quite big companies when compared to SMEs in Austria and Finland with firms that employ 5 to 10 employees. Germany lacks bio-informatic students. Critics mentioned the low in international orientation of universities as a barrier in biotechnology education.

Figure 7.1. Germany: Biotech employees in R&D in 1999 (total number of employees is 16 382)



Source: OECD 2001 Van Beuzekom

In the Netherlands about 1615 people were employed in biotechnology R&D in 1997, the number of researchers in biotechnology as a percentage of total researchers is 2.8%. (see the following table). The fact that biotechnology is more in the green than in the red domain explains the lower amount of researchers when compared with Germany. Ninety percent of all biotechnology R&D researchers are in the business enterprise sector. In manufacturing, the food products and beverages sector has the largest share of biotechnology R&D researchers. This is on the one hand due to the fact that the Netherlands are leading in green biotechnology among our countries, on the other hand to the fact that the definition includes "older/traditional" biotechnology.

Table 7.3. R&D full-time-equivalent employees in biotechnology and total in the Netherlands (includes "older/traditional" biotechnology)

	Total		Biotechnology		Biotech share in total sector R&D	Biotech share in total Biotech R&D
					Percent	
	1995	1997	1995	1997	1995	1997
Manufacturing	29 980	30 243	..	562	1.9	34.8
food products ; beverages	2 654	2 626	443	180	6.8	11.1
textiles and leather	182	213	..	2	0.9	0.1
paper	182	194	1	2	1.3	0.2
basic chemicals	6 412	2 311	72	x	..	..
pharmaceuticals, medicinal	2 253	2 966	89	x	..	..
other chemical products	..	2 659	..	27	1.0	1.7
rubber and plastic products	469	657	2	x	..	..
machinery and equipment	2 857	3 027	4	6	0.2	0.4
Services	..	9 808	..	553	5.6	34.3
Remaining sectors	..	2 358	..	359	15.2	22.2
agriculture, forestry and fishing	619	638	258	x	..	..
Research institutions (B-sciences[2])	15 070	14 311	120	141	1.0	8.7
Total business enterprises	37 116	42 409	1 344	1 474	3.5	91.3
Total	52 186	56 720	1 464	1 615	2.8	100.0

x = confidential.
1) These firms are operating in several two digit NACE groups. The common denominator of these firms is that they operate on behalf of private enterprises.
2) B-sciences stands for agricultural sciences, natural sciences, engineering and medical sciences (NSE).
Source: based on data from Statistics Netherlands (CBS) (http://www.cbs.nl/). Note: data from the Dutch CBS include research on genetic modification, cell fusion/biology, fermentation, development of proteins/enzymes, neuro biology, botanical improvement, bio catalysts. (http://www.oecd.org/dsti/sti/s_t/biotech/stats/Inventory/netherlands.htm)

Supply of skilled personnel is not an issue in Austria, at least not in the vicinity of Vienna. However, a comparison with other countries is rather difficult. Austria used to be a laggard in biotechnology and its attempts to catch up with more developed countries or regions is only from recent date (about 5 years). The demand for skilled personnel thus has been low, so that there was an oversupply of experts that was happily absorbed by other countries, in particular by Germany.

Profiting from the past, Austria has a good and famous medical tradition. Vienna educates about 3000 students of medicine, biotechnology, biochemistry and other biotech related fields per year. It furthermore trains 200 PhDs every year in biotechnology related areas. Demand for experts is much lower. Biotech start up activity is still in its infancy. Startings often start with small teams to get a business on its feet. After the initial phase and after having passed the first milestones, a company can extend its personnel. However, this has only meant ten to twenty new jobs in the Vienna Bio Centre in the past years. Demand will increase in the years to come, but still the Austrian education system is well able to provide qualified staff. Moreover, demand for qualified staff at universities is low. This may seem a contradiction, because a system that is able to train 200 PhDs will usually have a certain degree of mobility within its ranks. However, that is not the case. Universities have developed “into small micro environments of somebody knowing in terms of decisions when important jobs are filled”. Large selection committees have to reach agreement over candidates and often these committees have more than 40 members: professors, assistant professors and students. (The new university reform laws changed this. Now the rector can nominate the candidate, after a committee has suggested some candidates However, the fact that a rector of let’s say economics determines who the professor of biotechnology will be, does not sound very promising either). In this system only few positions are open each year. In fact, as a result, many Austrian scientists have to go abroad. Several companies in Martinsried, Heidelberg, or the US have Austrian scientists in their highest ranks.

The level of the Austrian education system is well respected in international circles. Austria, especially Vienna, traditionally has a good reputation in bio-medicine. Nevertheless, research as well as education are rather fragmented. A close review of the system shows a high degree of specialization among university institutes, some institutes which would make the “toolbox biotech” complete, are missing. This is certainly partly due to the smallness of the country. But Austria is not an exception: the dynamics of biotech research and education are not the result of well designed education systems but rather the outcome of patterns of specialization and adaptation, fitting into an international environment.

Austria produces an oversupply of biotech students for the very small Austrian biotech market. Investors mention the good training and education in biotech (interviews). It has a brain drain to Germany and other countries. Biotech is a field with a lot of international researchers, many start ups have attended US universities. Research Companies have a lot of post docs as researchers, whom they recruit from many countries. For example, the research labs of Novartis recruit researchers from universities, both PhD's and post docs from 35`nations. The Austrian problem is that the way back to university is almost impossible, and this discourages doing so. Once a person has left a university, he or she can rarely come back. (unlike in FIN and NL). Therefore, the relation between educational institutions and business organizations remains a traditional one in Austria: universities do contractual research for firms.

7.2.2. Education for Telecommunication

The quality of education and training in Austria has been and still is an important factor for a company's decision to settle in Austria. In telecommunications, engineers and technicans are trained in technical high schools = HTL (Höhere Technische Lehranstalt) belonging to the secondary educational level and terminate with the title of “Ingenieur” (engineer). On the tertiary level, there are FHs (Fachhochschule - polytechniques) and Technical Universities (TU) which both terminate with a university diploma, that is: *Diplomingenieur*. *Polytechnics* are organized similar to schools (duration: 8 semesters) and were only created in 1993 (Fachhochschulführer 2000), they do have closer contacts to companies and are more specialized than universities. There are 55 types of FHs, and about one third of all students study in the domain of telecommunications.

The sharp increase of polytechnical students is partly due to the fact that in the EU, the Austrian secondary school “engineers” are not accepted as much as within the country. But they provide about 3000-4000 “engineers” for telecommunications per year, Polytechnics provide another 2000-3000 Diplom-engineers and Technical Universities only about 100-200 for this sector. About the same amount of skilled labor is produced for the biotechnology sector. Given the small Austrian domestic market and the higher, more attractive salaries in Germany, there is a brain drain to Germany. The good Austrian educational system is both, an attraction for firms to settle down, and for firms abroad to higher Austrian labor. At the moment there is a fight for labour among companies both within Austria and from abroad.

The average duration of study which is 14 semesters (7 years) for electrical engineering was the main reason for the high university drop-out rate. The trend goes definitely towards Polytechnics.

In the Netherlands actually a decline in science and technology student shares was experienced between the 1960s and the 1980s. The popularity of electronics has fallen since. There is a decline of interest for science and technology. Dutch efforts concentrate more on increasing the entrepreneurial spirit.

7.2.3. A Case Study: The Finnish Education System in Telecommunication

The Finnish success story of telecommunications was accompanied by the development of a flexible education system for engineers. The education and research in telecommunications technology was institutionalized very soon after the invention of the telephone and its diffusion to Finland. The Polytechnic Institute of Helsinki began its teaching activities in the field of telephone technology as early as 1883 (see Finnish Report). This institute was the predecessor of Helsinki University of Technology (HUT), which was established in 1908.

The research and education activities were closely linked with actual technical issues of telephone companies as well as their needs of qualified manpower. Teachers came from telephone companies or worked for them at the same time. From this early establishment of university activities, result also research laboratories, which in the 1970s engaged in optical telecommunications.

In the telecommunications sector, the need for the educated labor force was and is extraordinarily high; most of the new jobs call for a degree at least in polytechnic level (Mannermaa & Ahlqvist 1998). For example, at L.M. Ericsson's units in Finland, half of the employed are engineers.

Finnish education institutions provide three kinds of engineering degrees: Master of science in technology, college engineer or engineer (AMK), and technician (Tulkki 1996, 14-15). The degree of the mechanic is traditionally completed in secondary VET schools. The Finnish vocational education and training system was reformed in the 1990s. The polytechnic reform can be viewed as the most important of these changes. This reform created a totally new stream of higher education. In 1995, the Ministry of Education announced the report 'Education, Training and Research in the Information Society – A National Strategy. According to it, the national goal for the Finnish education system should be "that professional competence in the different sectors of the information industry is counted among the best in the world" (MoE 1995). In practice, this challenge was understood as claim of increasing the telecommunication engineer education. And quite successfully: the number of telecom engineering students (universities plus polytechnic) is as high as 4,200, which is 6.9 percent of the age group of the 19-year-olds, compared to 345 students ten years before. In 1999 1,800 new students started their data processing education in polytechnics, twice as many as two years before.

In 1999, the Ministry of Education composed another new strategic plan of action, Strategy of Knowledge of the Education and Research 2000-2004, which was meant to further increase the number of students.

The Finnish example indicates the great importance of the flexibility of the education institutions and the whole educational system in the conditions of the new knowledge-based economy. The Finnish educational administration and the institutes of engineering education have answered rapidly and effectively to the challenge of developing the industrial branch of telecommunication technology and the information society. The growth rate of telecom engineering education in Finnish universities and polytechnics has not only ensured the skilled labour force for existing telecom companies, but also attracted global companies to locate their R&D departments in Finland. Particularly Siemens and LM Ericsson take advantage of the high standard of the Finnish engineer education and know-how of the Finnish telecom industry in their R&D units located in Finland (TIEKE 1999, 11-14).

Finland actually has a strong tradition in using education as an instrument of adaptation to the situations of radical socio-technical changes. Education also has a role in generating the markets for the products of telecomunication industry. Finland has invested a lot in adult education, aiming at famiilarising the Finns with telecom equipment and technologies. The Committee for Lifelong Learning, inducted by the Council of State, set the aims for the policy in its committee report 'The Joy of Learning':

Critics state that the Finnish flexibility goes sometimes too far. Schools get quickly transformed into polytechnics, when needed. This means, that the number of "universities" in Finland is overestimated by international comparison. The fact that Finland has five times more universities per head of the population compared to the countries considered in our study is mainly explained by the training of engineers. However, the Finish example shows, that education policy can play an enormous role for the location of firms and innovative activities.

7.3. Finance

Further institutional contrasts between our four countries that influence their innovative performance concern their financial system. The financial system influences ownership and the extent to which there is finance for high-risk investments. Our countries differ substantially in the degree of importance of the equity market versus banks as capital providers. That should have consequences for innovation, assuming that radical innovation usually requires more risky investments. Credit based systems, with capital channeled largely through banks, tend to produce more patient and growth seeking financiers, with long term orientation but also a certain risk aversion, than do equity financed systems (Soskice 1991, Whitley 2000).

7.3.1. Bank Based versus Stock Market Based Financing

Austria and Germany belong to the bank based financing systems. This is due to historic reasons, where the stock market crash in the 1870s made the civil servants of the monarchy very hostile to stock markets and resulted in a tax on stock market trading. As a consequence, the German and Austrian stock market developed much slower than the Dutch, and Finnish lately. As the German report states, the German bank based system is long over. With the creation of the Neuer Markt in Frankfurt for high tech stock market, financing is easier than before. In Austria, however, the bank based tradition still dominates and results in very careful financing.

In Austria, nationalized banks had to provide some venture capital to some firms (see Austrian Report on Biotechnology). Austrian Banks ask for a lot of guarantees, they are used to state guarantees, but this does not work with firms that work with international capital. Austrian banks judge high tech projects more risky than a hotel in Bukarest (Interview Intercell). With EU membership increased competition among Austrian banks and privatization led to mergers, and changed this arrangement of nationalized banks. In addition, the liberalization of capital which started in Austria late (in 1987) brought after some learning effects, access to international financial markets. The access to the German stock market (Neuer Markt Frankfurt) is much easier now.

7.3.2. The Stock Market

An indicator for the importance of the stock market is the value of equities issued in percent of GDP. Market capitalization of domestic equity issues is still extremely low in Austria (the value of all noted equities is 15% of GDP in 1996), and also relatively unimportant in Germany (28%). By comparison it is high in the Netherlands (95%). (In the US the stock market is even more important, with the turnover of marketable equities being 114% of GDP). In Austria the government and banks finance themselves via the domestic capital market (through bonds, i.e. fixed interest rate assets). Industry finances itself via bank loans and own capital. The fact that there is little experience in stock exchange trade and that

Table 7.4. Market Capitalization, 1997

Country	Stock Market capitalization		Number of companies	
	billion Euro	in % of GDP	domestic	foreign
USA				
- NYSE	8,045	134	2,271	355
- NASDAQ	1,574	26	5,033	454
Japan	1,957	54	1,805	60
EU 15	4,946	70	6,004	
Belgium	124	58	136	127
Denmark	85	59	237	12
Germany	751	39	700	1,996
Greece	31	30	200	0
Spain	265	55	384	4
France	613	49	683	179
Ireland	48	78	77	10
Italy	314	31	235	4
Luxembourg	31	222	56	228
Netherlands	427	133	201	149
Austria	33	18	101	36
Portugal	35	40	148	0
Finland	67	65	124	2
Sweden	242	114	237	16
Great Britain	1,879	194	2,465	526

Source: Huffschmid 1999: 34

the market is very thin makes Austrian assets rather high-risk assets. A Japanese firm buying some Austrian shares can already create big turmoil in the Austrian Stock Exchange. Finland is a special case. The relevance of its stock market increased in the 1990s tremendously and was 49% in 1996 (see Adjustment Data Base). However, the illiquid money market was a serious handicap to investment and innovation in the early 1990s.

The importance of the stock markets makes the financial systems of Finland and the Netherlands more vulnerable to international capital movements, but provides also a source of capital for more risky investments in innovation. This more flexible capital market seems to correspond with responsive corporatism in these countries. By contrast, rigid corporatism and more conservative bank finance seem to go together in Germany and Austria.

Finance was the hampering institution under the old paradigm in telecommunications. Public providers complained that they could not expand flexibly, because they had to get the permission of the government for additional finance. In the Netherlands, in Germany and in Austria this constraint was emphasized. In Austria, for example, the *Kapitalmarktausschuss*, a social partnership determined board, had to decide whether a state enterprise could issue additional bonds . The capital market for fixed interest rate assets had the almost exclusive task to raise private funds for state companies. It was abandoned only in the late 1980s. Financial drought was one of the major reasons to privatize telecommunications in these countries. In Finland there was always some competition among providers that allowed for a more flexible way of financing. For big producers, finance does not seem to have been a major constraint and was not so much nationally influenced. Big multinational telecommunication companies can finance themselves worldwide. None of the four countries mentioned financing difficulties in telecommunications today. (Though there were some difficulties and turmoil to privatize the post and telecommunications company in Austria in the late 1990s. The shares had been issued at a wrong price).

7.3.3. A Case Study: Austria: Financial Impediments to Innovation

Austria lacks stock market financing. Internal finance, by which we mean financial resources of a company that are used for investments and which are normally generated by sales, are next to bank credits the most important source for R&D in Austrian telecom companies. The public sector covers only about 5% of corporate R&D (that is public funding for business, see section above), a share that is unusually low among EU countries.

Key companies with some relevance to the Austrian R&D activities in the telecom sector are three equipment companies which are subsidiaries of foreign based firms. Alcatel Austria and Ericsson Austria, are stock companies (Aktiengesellschaften) owned to 100% by their parent companies, not traded at the stock market, and depending on the parent company policy for any investments in R&D (Interviews 21, 22). Siemens Austria, also a stock company not traded, is owned to 74% by Siemens Germany and to 26% by the state-owned Austrian ÖIAG. Investment matters are usually decided in Munich (Interview 16). All parent companies, Siemens, Ericsson, and Alcatel are traded at several stock markets. The Austrian company Kapsch was also a joint-stock company but family-owned to 100%. None of these companies is traded at the Börse Wien (Vienna stock exchange).

The only company traded at an alternative stock market was the Styrian supplier AT&S, which has a free float of 26.7% at the Neue Markt, Frankfurt. The remaining shares are owned by the CEOs and the employees. AT&S is also very R&D intensive, and needs the capital generated through the IPO for future investments in R&D on new materials for developing a new generation of PCBs. It is interesting to note that AT&S is also the only company on the larger supplier sector giving out stock options to employees. This modern form of employee-ownership is still very unusual for an Austrian company.

Finally, Telekom Austria is also a stock company, owned to 75% by ÖIAG (Republic of Austria) and to 25% by Telekom Italia and fully privatized lately . Until 1996, when the Post- und Telegraphenverwaltung (PTV) was turned into a stock company, the investments were regulated by public act, the telecommunication investment act (Fernmeldeinvestitionsgesetz=FMIG). Sincet telecommunication was the only unit of the former PTV generating any profits and that most of these profits were used to cross-subsidize those units that were not profitable (post and bus). In order to secure at least some investments, the FMIG regulated the amount of money that could be invested in telecom infrastructure and the like annually. If this was not sufficient for the investment needs of the PTV, additional money had to be acquired on the bond market (PTV 1986).

The Austrian bond market (for securities with fixed interest rates) was not a source of financing for companies in general, especially not for Austrian private telecommunications companies. Partly because of the required company size and creditworthiness, partly because of cheaper since highly subsidized and more attractive bank loans. Thus issuing transactions are dominated by the state and banks[9], whose share of gross emission in initial public offering (IPO) ranked between 82.1% in 1983 and 95.2% in 1980 (Brandner 1991: 633).

Besides, the bond market was highly regulated by the *Kapitalmarktausschuß* (Committee for the capital market). This *Kapitalmarktausschuß*, which was established in 1979 and consisted of representatives of Austria's biggest banks and the Ministry of Finance, regulated and stipulated quotas for the total volume of emissions[10] and fixed nominal interest rates. Due to external pressure for liberalization Austria's liberalization of the capital market started in 1987. Its attempt to adjust to EU capital market structures necessitated that, the strong regulation practices were changed. In 1992, when the law on capital markets (Kapitalmarktgesetz) was implemented, also the *Kapitalmarktausschuß*. was abolished .

The Austrian bond market was the domain of the federal government, state governments and state-owned energy companies. This practice continued until the 1980s (!) when Austria attempted to adjust to EU capital market structures (Goldmann 1990b: 48-49, Brandner 1991: 637). It definitely hampered the growth of industries that were capital intensive. This is to say that corporate investment in R&D which is usually seen as a risk by banks could not be financed and small companies were not able to expand. Especially the potential growth of high-tech companies which are R&D driven and require a lot of equity, was blocked.

There is only one stock exchange in Austria, the Wiener Börse. Regional stock exchanges as in Germany (Berlin, Hamburg) do not exist. Venture capital markets or an alternative stock exchange as they are now emerging in other EU countries (Neuer Markt in Frankfurt, Germany) do not exist in Austria either. Besides, in the telecom sector there is only limited need for venture capital as the equipment companies are all traditional players and the emerging providers and operators are owned by other established, most foreign companies.If a high-tech company wants to raise equity at an alternative stock market, Austrian firms are likely to be listed at the Neue Markt, Frankfurt. So far, this happened only in the case of AT&S the Styrian component supplier (see above).

The Austrian-Hungarian Empire bureaucracy was hostile to stock markets since the crash of 1873. Therefore, a securities sales tax was introduced (in 1892) which made emissions and trade at the secondary market unattractive (Goldman 1990b: 48). This induced companies that were in need for funds to establish close relations with their "house banks". Tax reduction policies for bank credits supported a conservative corporate finance policy A bank based system rather than an equity based emerged (similar also in Germany). The nationalization of key industries after World War II also dried out the stock exchange: 73% of share capital went private in 1946/47 (Baltzarek et al 1998: 43). In the 1970s and early 1980s, the stock exchange/ liberalization (market allocation) of the financial system was still not of high priority to the government that followed Keynesian policy principles. Today the Vienna

---

[9] In 1980, the public sector emitted 67.5% of IPOs of fixed interest bearing securities; banks: 27.7%; companies: 2.4%. In 1990, the public sector emitted only 46.2%; companies: 5.3% and banks: 41.2% (Brandner 1991: 634).

The quotas were easily enacted since every emission on the bond market had to be confirmed and allowed by the Ministry of Finance. This was changed in 1992 when the Kapitalmarktgesetz came into power.

stock market is rated “too thin” a market, minor trades can produce a high volatility of assets. This makes it a very risky stock exchange.

Compared to the other three countries, Austria ranks lowest in market capitalization at the stock market (see Huffschmid 1999:34).

In addition, Austria traditionally discriminated stock companies by highly regulating them and through high taxes on the company itself but also on profits and dividends[11] (Baltzarek et al. 1998: 41). In 1983, Austria had 555 public and private stock companies, only 50 were listed at the Vienna stock exchange (of which again 75% were already listed during the monarchy!) (Beirat für Wirtschafts- und Sozialfragen 1985: 66).

Having a look at the industries[12] of those 50 listed companies, makes it evident that emerging industries (e.g. oil, computer industry ..) were missing all together. The lack of growth industries also had a negative influence on the Vienna Stock Market's attractiveness. Besides, it was a very thin market. Estimates were that the free float was between 15% and 22% only (Beirat für Wirtschafts- und Sozialfragen 1985: 67) in the 1970s and 1980s. The stock market gained importance starting in the mid 1980s though. However, changes in the organization of the stock market were again induced from outside (Hofbauer 1990: 264). Privatizations - starting in the late 1980s - also stimulated the stock exchange, thus encouraged private companies to go public. In 1991, the Vienna stock exchange quoted 91 securities, Frankfurt had 630 securities quoted, the NYSE 1,721 and more than 2000 securities were listed in London (Bayer and Hahn 1991: 291). When looking at market capitalization Austria still ranks at the bottom (see table 5). Besides the number of persons holding shares too, rose only from 1% of total population in 1985 to 4% in 1997, compared to Finland (20%), Netherlands (5.8%) and Germany (5.4%) (Baltzarek et al 1998: 42).

The Austrian financial system is definitely not designed to support businesses that are capital and R&D intensive. Rather, it is a system that – as so many other institutions in the Austrian innovation system – is security oriented and tries to avoid risks. The bank based system had a conservatory effect on the Austrian industry structure which is dominated by small and medium sized firms (99% of all businesses have less than 500 employees) operating in traditional sectors. Only a few big and state-owned corporations were able to meet the requirements for acquiring money on the capital market. New ideas and emerging technologies could thus not be funded. Even today, high-tech companies in need for high equity are likely to turn to foreign capital markets.

Austria’s predominant mode of financing is through banks, who function according to the universalistic principle, i.e. unlike in the US, they do all types of business (also the

---

[11] E.g. Doppelbesteuerung auf Dividenden.

[12] *Table 7.5. Companies listed on the Austrian tock exchange in 1983, by sector*

1983	# of listed companies	quoted capital stock	Market value in million Euro per 15.12.1983
Banks	2	3,150	8,160
Building industry	7	838	2,122
Mining industry	3	608	1,254
Chemical industry	6	2,108	3,312
Electrical & engergy industry	4	766	2,281
Beverage industry	5	803	2,269
Food and Sugar industry	3	410	1,545
Maschines and metal industry	10	2,654	4,255
Paper industry	4	1,274	1,399
Textile industry	2	93	155
Insurance	4	930	4,715
Total	50	13,635	31472

Source: Beriat für Wirtschafts- und Sozialfragen 1985: 66

reselling and re-buying of equities and bonds at the secondary market). Austria even strengthened the dominance of banks by subsidizing loans. In 1989, 42% of loans were subsidized (Schaumayer 1991: 239).

The share of public support for industrial research is negligible, the biggest share is spent on basic research an universities without any strategic application. Especially small businesses are likely to suffer from this structure because they do not have the lobby to shop for subsidies as a company like Siemens, and any efforts to engage in R&D are blocked. This security oriented pattern, trying to conserve the existing structure is also repeated in Austrian technology policy and not of much support to the national system of telecom innovation.

Today, one can conclude, financing is not any more a major constraint in telecommunications. But in biotechnology the financing of start ups can still be hindered or promoted by national financial institutions. Biotechnology firms usually start as small companies, as spin offs from universities, that do not have much know how to raise international funds. They are too small to figure at the stock market, and they are too little known to attract international venture capital.

7.3.4. Venture Capital

There are two main sources of venture capital. First, specialized firms which act as intermediaries between firms and financial capital suppliers (in particular pension funds and banks) provide formal venture capital. Second, „business angels“ usually wealthy individuals, experienced in both business and finance, invest directly in firms. According to OECD estimates, business angels invest more than twice as much in new firms than do formal venture capital funds in the US. For Europe this might be less, though.

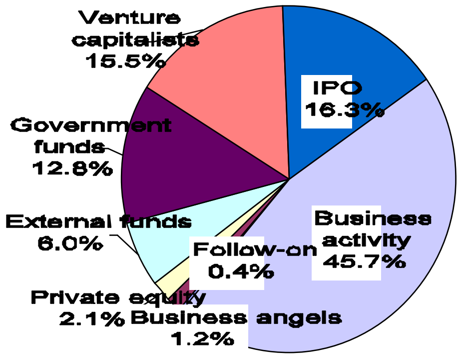
Formal venture capital covers different stages of financing of a venture-backed company:

1. Seed capital: to research, assess, and develop an initial capital
2. Start-up: for product development and initial marketing. The firm has not sold the product on the market yet.
3. Expansion of the firm

(OECD, van Beuzekom 2001)

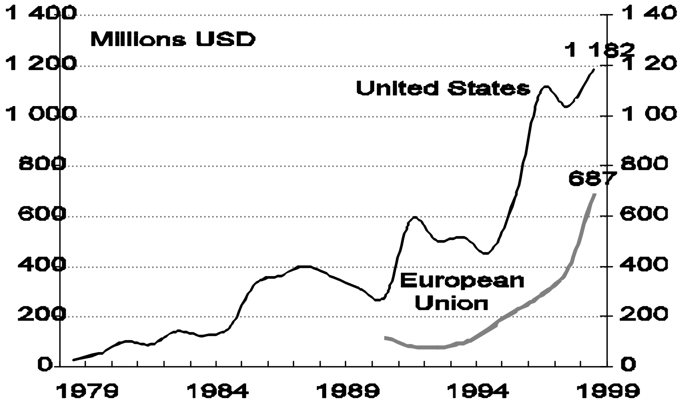
Venture capital investments on biotechnology in 1999 per thousand units of GDP was highest in Germany with 0.15, followed by the Netherlands 0.09, Finland 0.07 and Austria 0.01 (see OECD, van Beuzekom 2001, p.27). Also the venture capital intensity in the total high tech sector shows the same ranking D-NL-FIN-A (see graph)

Figure 7.2. Where do biotech SMEs go in search of funds?
Resource allocation in 1999



Source: Ernst & Young, “Biotech in Germany, 2000”. (http://www.ernst-young.de/)

Figure 7.3. Biotechnology and Venture Capital: US and EU[1] venture capital disbursements for biotechnology firms, 1979-98



Source: OECD 2001 Van Beuzekom

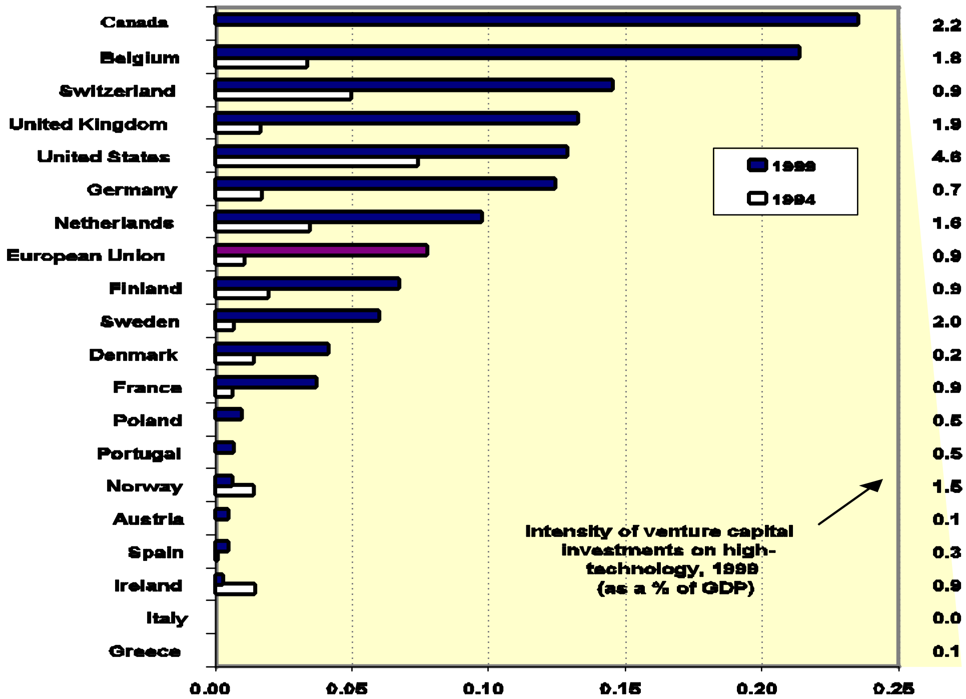


Figure 7.3. Venture Capital Investments on Biotech 1999 per thousand units of GDP

New biotech firms have high start-up costs. Survival of the first four years is expensive, once if there are interesting findings in basic research, one can immediately transport it into applied research and sell it (e.g. enzymes).

Risk Finance was certainly a lack of the Austrian National Innovation System. But with the globalization of capital this disadvantage is reduced. But for small firms this can be still a handicap if they do not have already international connections and support.

7.4. Conclusion

From some of the case studies one can see how national institutions can influence the performance of a sector. The huge effort that the Finns put into public policy and education for biotechnology and telecommunications is striking. The restrictions of finance and law on Austrian biotechnology plus the lack of technology policy for a long time can partly explain the relative poor Austrian performance. Germany puts a lot of money into both sectors and successfully performs, but at high costs. However, the German education system is too old fashioned to cope with new demands of the new technologies. The Dutch seem to play a distinguished role. They put their emphasis on the development of the entrepreneurial spirit, a historically well experienced way of the country, trading since the 15th century.

In both sectors the decline of the influence of national institutions can be noticed. Firms can recruit personnel from the US and sometimes pharmaceutical companies have people from 35 countries working for them. Telecommunication is even more globalized, and dominated by global big players. However, national institutions created path dependency. The legal restrictions in Austria for biotechnology hampered green biotech. The lack of finance and of technology policy created the situation of a laggard to international technological developments.

Chapter 8. Institutions: Innovation Policy

Gerd Schienstock

8.1. Introduction

Because biotechnology and telecommunications are both rapidly evolving industries, it is difficult to draw clear conclusions about how to design an appropriate innovation policy[13] to support their development. Different policy approaches may be useful for different stages of development; what may have been effective at the very early stages of development may be less effective at the later stage of industry formation. In general, one can argue that policy makers have become more sophisticated in designing innovation policies, particularly in biotechnology, as they could learn from experiences in telecommunications. This holds at least for the Finnish innovation policy.

In addition, policy makers are more prepared to learn from others, sometimes using competitive benchmarking as a measure to identify good practices and to improve policy strategies. Most often policy makers cast their eyes on the US as the US seems to be far ahead of Europe. However, the German BioRegio Programme has also been copied by some European countries, including Austria.

8.2. Financial Support and Regulation

Technology policy in the public domain pursues, as Braun (1994) argues, two broad objectives: to enhance and accelerate the development and use of technology, on the one hand, and to regulate the application of technology on the other. Financial incentives as direct subsidies or tax relieves have been in the core of the traditional innovation policy approach. Government charges as well as taxes and related compliance costs matter for all firms, but they can particularly impede firm start-ups and the growth of small firms based on innovation. Therefore, reducing these costs may to some extent foster research and innovation activities.

In the Netherlands R&D is promoted by granting firms a **40% discount on salaries** paid to R&D personnel for the first **150,000 guilders** and an **additional discount of 17.5%** for salaries paid for R&D personnel with a maximum of **15 million guilders**. Mostly SMEs have participated in this measure; however, companies from telecommunications and biotechnology industries have benefited relatively little from this instrument. In general, one can conclude that these financial incentives are too simplistic in an environment in which innovation and knowledge are the key assets.

Economic success in developing a knowledge-based industry, such as telecommunications or biotechnology, depends on other factors such as skilled labour, first class

[13] Here we have a wider understanding of innovation policy; it includes science and technology policy as well as innovation policy in a narrow sense.

universities and research institutes, risk-taking venture capitalists, sophisticated customers and entrepreneurship, and an innovative culture. Therefore, governments increasingly rely on a more complex, systemic approach, which focuses on economic, organisational and institutional aspects. It is not by chance that governments applied the concept of national systems of innovation (Lundvall 1992, Edquist 1997) when they turned their attention to the development of new knowledge-based industries. The Finnish Government was actually the first in all OECD countries to apply the innovation system approach to develop the telecommunication industry and thereby to overcome the deep economic recession in the early 1990s.

While the aim of financial incentives is to support and to accelerate the development and use of technology, the aim of regulation is to eliminate or to minimize risks posted by technology to health safety, the social fabric, and the natural environment (Braun 1994: 97). Such a dualistic approach, which first supports the development of a new technology and then aims at dealing with possible risks, has some major limitations. For example, with respect to ethical aspects, it might be necessary to block specific development paths through legal regulations, as is the case with human cloning research. In this case, it is not possible to first nurse the vegetables and then pull out the weeds (Mayntz and Scharpf 1990: 61). It is important not to allow the weeds to grow.

On the other hand, it is often the case that the development of innovations is hindered by existing legal regulation, which means that one cannot participate in the benefit of an innovation which might be more valuable than the elimination of some risks associated with the innovation. In such cases, de- or re-regulation may be more effective in supporting the development of a new science-based industry than financial incentives. For example, shortening the procedures for the approval of biotechnology facilities or field trials in some German federal states has been very supportive of the development of the biotechnology industry (Kaiser and Grande 2001). And early deregulation in Finland has contributed significantly to the development of the telecommunications sector.

8.3. Knowledge Creation

Knowledge creation can be seen as an important part of the idea-innovation chain and as a key area of innovation policy. However, it is highly controversial at what stage innovation policy should intervene in the knowledge creation process. When countries started to develop an innovation policy, they were mainly concerned with the creation of new scientific knowledge. Based on the ‘cascade model’ of technological progress (Schienstock 1994), it was assumed that the innovation process depends exclusively and linearly on the advances of natural and technical science. The rationale of such an approach followed from the ‘market failure’ concept (Arrow 1962), which suggests that the state should compensate for companies’ withhold from basic research, motivated in particular by the high uncertainty associated with the development and application of new scientific knowledge (see Chapter 5 for criticism of the linear model).

Krueger (1991) has warned, that public technology policy will not always improve welfare; instead; there is a high risk of government failure. For policy makers it is very difficult to select those technologies that promise future economic growth, because they do not often have the knowledge to decide which technologies will become successful and be selected by the market (Schienstock 1994, Metcalfe 1997, 275). Due to path dependency of technological development, there is a danger that such direct technology policy will cause faulty developments. Also, the fact that in knowledge-based industries we cannot clearly separate science from technology speaks against a focus on direct technology policy; the frontier between science and technology is more and more blurring: the planning of concrete technological applications of basic research is often an impossibility. In fact, in knowledge-based industries, basic scientific research is increasingly nurturing innovation; new discoveries may not only increase scientific knowledge but may as well lead directly to successfully commercialized innovation (OECD 1998).

Governments in the four countries that participated in the research project have invested a significant amount of money to extend the national scientific knowledge base in the two industries. For example, the German Federal Government invested in the academic infrastructure in biotechnology and established four National Centers of Genetic Research in Berlin, Cologne, Heidelberg, and Munich. The selection aimed at strengthening those regions in which the scientific infrastructure was already strong. In Finland, the 'Centers of Excellence' Programme, which has become a major activity of the Academy of Finland, also aims at improving the quality of basic research in knowledge-based industries by fostering the concentration of scientific talents.

Furthermore, all four governments have launched several programmes to support the development of research in telecommunications and in biotechnology. In the late 1990s, the Austrian Government, although a latecomer in developing innovation policy, designed a programme called "Technology Billion", which for the first time made possible a focused funding on a few targeted research fields, among them micro-electronics and informatics as well as biotechnology and genetics (Unger et al. 2000). However, in most cases, these governments pursued an innovation policy of picking winners. For example, the aim of the R&D programme Biotechnology 2000, launched by the German Federal Government in 1995, besides supporting the development of the basic R&D infrastructure, was to promote specific technologies and methods in biotechnology (Kaiser and Grande 2001: 40–42). Preveser (2001) argues that this emphasis on direct funding of specific technologies may explain why the German biotechnology policy intervention had conspicuously little success.

Federal funding in the US, on the other hand, went to basic research and no attempt was made to fund biotechnology *per se*; this may have been decisive for the successful establishment of the new industry (Preveser 2001). This argument supports Pavitt's (2000) claim that industrial demand is often satisfied by unexpected scientific discoveries and technological opportunities. Unexpected but scientifically as well as economically very important research results cannot emerge if basic research is controlled by external demand. Both aspects speak against the direct technology policy approach aiming at a close control of the practical relevance of scientific research. Instead, as the OECD (1998) argues, there is a need for a high-quality science base that develops independently and is not influenced by external pressures for practicability and relevance. Particularly at the early stage of the development of a biotechnology and telecommunications industry, a strong national or regional scientific knowledge base is decisive.

Developing a knowledge-based industry therefore depends to a great extent on the availability of scientific talents capable to conduct high-quality basic research (Audretsch 2001). Establishing first class universities and research institutes can be seen as an important part of innovation policy. But it is not only the availability of scientific talents which matters most, as important is the movement of scientists between research centres and industry as a natural mechanism of transferring tacit knowledge (Prevezer 2001: 27).

The late takeoff of the German biotechnology industry may also be explained by the fact that scientists seldom moved between research centres and industry, which means that transfer of tacit knowledge took hardly place. The German Government, on the other hand, was only lately active in providing incentives for scientists to step out of universities and non-university research centres and to commercialize their scientific knowledge (Kaiser and Grande 2001). The scarce movement of scientists between university and industry also causes problems of knowledge transfer in other countries. Governments have tried to compensate for the scarce movement between science and industry by establishing third party intermediaries such as technology transfer offices. But these can poorly substitute for the direct information flow between the science base and industry and collective knowledge creation (Shohet and Prevezer 1996). The Finnish telecommunications sector represents a positive example: movement between science and industry is more common in the sector, partly because a major aim of Finnish innovation policy was to establish innovation networks in which universities and industry co-operate intensively in the development of new knowledge.

8.4. Institutional Support Structure

As we have argued earlier, new scientific knowledge is crucial for innovation activities in knowledge-based industries but this knowledge is not applied automatically. The transformation of knowledge into new products and processes needs to be organised in an efficient way.

To capture the systemic, interdependent character of innovation and technical change (Soete and Arundel 1993, Freeman 1997), policy makers have taken the innovation system approach as their basic conceptual framework. Policy makers then have to ask the more general question of where and how the performance of the innovation system is weak (Edquist 1997). They should be concerned to influence the innovation process wherever it gets stuck, instead of imposing predetermined outcomes, as with direct technology policy (Metcalfe 1997: 275).

This suggests focusing on systemic failures characterised as mismatches between components of an innovation system (OECD 1998, 102). A dynamic, highly interdependent and complex innovation system can suffer from many different types of systemic failures: from infrastructure failure, organisational failure, institutional failure, transformation failure, or lock-in failure. Based on the concept of systemic failures, innovation policy increasingly focuses, instead of technological aspects, on social aspects of innovation. We may talk about the new approach as innovation-enabling policy (Schienstock 1994).

One area of the new approach is the setting up of a supportive institutional environment. Cohen and Fields (2000) have mentioned a long list of institutions supportive for the emergence of a science-based industry in Silicon Valley: high-quality universities oriented to collaboration with firms, venture capitalists, specialised law and accounting firms, high mobility of the workforce within the district, stock options for the employees, and people with different cultural backgrounds. The availability of venture capital is probably an important part of a supportive institutional environment because the formation of new companies and the development of new industries are associated with high financial risks. In all four countries, governments have put a lot of effort in increasing the availability of venture capital for knowledge-based companies. Concerning the commercialization of biotechnology, the Federal Ministry of Economics and Technology (BMWi) in Germany plays an important role as a provider of equity capital, especially for small and medium-sized companies (Kaiser and Grande 2001: 43). Also, in the three other countries, governments have contributed significantly to the increasing availability of venture capital. Starting a new business in knowledge-intensive industries in Europe is much more difficult when compared to the US, where private venture capitalists play a significant role in the early development of new science-based industries.

In several respects, labour market conditions also play an important role as innovation-supporting institutional factors. Science-based industries require the existence of qualified personnel of various levels of education and different areas of knowledge. Also from the demand side, labour market conditions play an important role, because the success of new products very much depends upon highly competent customer firms (OECD 1998). And in the start-up phase of new businesses, the local market is often very decisive. When local customer companies employ a highly educated workforce, the use, demand, and easy acceptance of new technologies is more likely. In the four countries, governments have recently increased the number of study places in universities and polytechnics in the two high-tech industries.

Regulation is another factor relevant to economic development and innovative activities. High costs of regulation can become a major hindrance factor for the establishment of new companies and the development of a new science-based industry. Blakely et al. argue that, with respect to biotechnology, “predictable applications of regulations concerning environmental and public health and the use of land are crucial to the location of biotechnology firms. Companies must be assured that their development activities will not be hindered by inconsistent applications of regulation” (1993: 23). Early deregulation of the telecommunications market in Finland, which has stimulated competition among foreign and local equipment produces, is seen as a major factor that can explain the innovative strength of Finnish companies in this sector (Schienstock 2001).

The presence of an entrepreneurial culture is also important for the development of a new knowledge-based industry, because it creates opportunities for a scientist to change his career trajectory and shift it away from research to commercialization. Of course, governments’ capacity to create an entrepreneurial culture and to influence young scientists’ career patterns are limited. However, to some extent, governments can create an innovative milieu, in which scientists are prepared to shift their career perspectives.

Of particular importance is the creation of socio-economic vision for a country or region, which indicates a government’s determination to a specific development path. In Finland, the ‘knowledge society’ can be seen as the new national vision that has become the guiding principle of socio-economic development and triggered the establishment of new start-ups in the knowledge-intensive industries (Schienstock and Hämäläinen 2001). In the Netherlands, the Ministry of Economic Affairs has strongly contributed to the development of an entrepreneurial climate by monitoring interesting projects and reporting about them, promoting benchmarking studies, organising congresses and seminars, giving out brochures and research reports, and similar activities (Oosterwijk 2000: 105).

To improve firms’ organisational capability to produce, accumulate, transform and diffuse knowledge in a more effective way is a second focus of the new innovation policy approach. Organisational forms in innovation systems “do matter” as Dosi and Marengo argue, “because information flows and behaviours differ according to the particular ‘institutional architecture’ of each system” (1995: 158). Initiating and enabling organisational innovations, including the intelligent use of modern ICT, the development of new skills and competencies, the installation of new work regulations, as well as the establishment of an innovative business culture, is at the core of a more complex innovation-enabling policy. In all four countries, several programmes to transform the firms’ organisation to adapt to the growing innovation competition exist, but they are hardly tailored to the specific needs of knowledge-intensive businesses. In some cases, support with respect to organisational aspects is part of a network-facilitating innovation policy.

8.5. The network approach

The important theoretical and policy problem posed by the innovation system approach is that innovations are generated not only by individuals, organisations and institutions but also by complex patterns of interaction. This means that the problem is not only to embed innovative actors in an environment of supportive organisations but also to enforce and facilitate communication, co-operation and knowledge exchange within innovation systems. In the governance literature, networks are seen as being superior in stimulating collaborative innovation and interactive learning compared to markets and hierarchies (Schienstock and Hämäläinen 2001). To what extent companies are prepared to co-operate more closely with other companies, including even competitors, and whether they are prepared to tie up in networks, depends upon public policy to a great extent (Powell 1990). As trust among network partners, an indispensable precondition for the functioning of innovative networks, does not occur immediately but emerges slowly and has to be learned, policy makers have a crucial role in the innovation process, as they are accepted as a neutral third party (Sabel 1997). To strengthen existing innovation-related networks and to help build networks in areas where they are lacking is seen as an important function of public innovation policy.

We have to take into account the diversity of networks: science (university, research institutes) - industry networks, (global) strategic alliances and joint ventures, large companies and SMEs, manufacturing and service (KIBS) firms, supplier networks, customer-producer co-operation, functionally specialised networks (R&D, standardisation, marketing, etc.), public-private-partnerships. Different types of networks become important at different stages of the evolution of a new science-based industry. The existence of networks co-ordinating the relationships between industry and universities, for example, is important at the first development stages of new industries, while later on close co-operation in inter-firm networks and producer-user relationships become more important. Prevezer argues that the successful development of biotechnology in the US can be explained to a great extent by the strength, density and variety of innovative networks. “US start-ups have had the advantage of the eagerness of US incumbents to get involved with them, for a multiplicity of reasons, but principle in order to have access to these new technologies” (2001: 27). As such a density of similar networks is lacking in the European biotechnology industry, it becomes a major target of innovation policy, she concludes, to foster close co-operation and network formation among companies and with other key actors.

Networking is a key issue in the “Twinning” initiative carried out by the Dutch Ministry of Economic Affairs. This programme is mainly active in the telecommunications sector. The aim of the programme is to promote start-ups particularly in knowledge-intensive industries by making available venture capital, housing, organisational support and advice. Between companies, some kinds of partnership relationships exist; larger companies, mostly KIBS, provide services to small emerging firms under favourable conditions. Partnership is of mutual interest; the Twinning companies can develop in a supportive environment, while the advising firms have access to edge-cutting developments and technologies. Companies are very interested in participating in such network activities, because sharing ideas can not only reduce uncertainty and collaborative innovation activities but also help reduce costs (Oosterwijk 2000: 105–106).

8.6. A Finnish network approach

In the following, we will briefly describe the various steps of a network policy approach focusing on inter-firm co-operation pursued by the Finnish National Technology Agency (Tekes):

- *creating awareness of networking opportunities* (organising seminars and distributing information through various media)
- searching for network partners (providing information on firms and support organisations, creating virtual and real meeting points (trade fairs), offering brokerage services, identifying emerging and fragile networks)
- building trust and shared knowledge base (time: slow start to create an atmosphere for developing trust relations, offering long-term perspectives, interest: identifying concrete benefits, offer (financial) incentives to participate)
- *organising the network* (finding a strong ‘flagship firm’ to act as a co-ordinator, establishing rules of co-operation, finding additional national and international partners, expanding subsidised consulting services (KIBS firms))

- *adding complementary resources* (technology: supporting the use of ICT technology, human resources: offering training activities, exchange of personnel, organisation: initiating organisational change, product market: creating or stimulating demand, institutions: setting standardisation and initiating technical norms, adapting regulations, business activities: fostering specialisation, adding R&D capacity)
- *stabilising and renewing the network* (evaluation of the programme, international benchmarking, exchange of experience and policy learning, adding new partners)

From the experiences of Tekes, we can learn that it is also important to deal with such network failures as the following, for example:
- closure and exclusion strategies of dominant partners
- conflicts and power games in processes of continuous negotiation and adjustment (sub-optimal solutions)
- free-riding the network building investments and activities of other partners
- difficulties to achieve swift and well co-ordinated adjustment (deferring important decisions)
- risk aversion due to network-specific investments and close interdependency (inflexibility and lock-in).

European governments in general and in the four countries in particular have only little experience with a network approach of innovation policy. A clear policy focus seems to be on science-industry relationships to foster collaborative knowledge creation and accelerate knowledge transfer. To stimulate co-operation among SMEs or of SMEs with larger companies is another priority in network policy (Schienstock and Hämäläinen 2001). In general, programmes have only minimum formal requirements, emphasis is put on flexibility. In most cases, the management of the network is left to the network partners. Government agents only give some administrative help and they provide different kind of information. While the technological dimension is dominating, some programmes also include aspects of organisational restructuring and human resource management.

A shift in the design of network programmes seems to have taken place recently. While earlier "top-down strategies" predefining technological areas and selecting strategic industries have been dominating, governments now increasingly apply a "bottom-up approach", encouraging self-organising networks. Governments seem to understand themselves more as facilitators, rather than as doers (Schienstock 1994).

8.7. The Cluster Approach

During the 1980s, agglomeration economies or industrial districts (Sabel et al. 1987) were seen as most favourable to initiate innovation processes. Agglomeration economies are characterised by the concentration of companies from one and the same industry or industrial sector in specific spaces. Porter (1990) argues that the role of domestic rivalry in agglomeration economies is a major factor promoting the continuous upgrading, which is necessary in achieving sustainable competitiveness.

The more recently discussed cluster approach, however, assumes that territories can gain more from interaction between industries than from industrial specialisation. For example, this is the case with the pulp and paper industry or the food industry, which are often seen as not being very innovative because they do not invest in R&D extensively. However, opportunities for technological development do exist, in these low-tech industries as well. But they are mainly related to the use of knowledge created in other high-tech industries such as the biotechnology industry. In Germany, the chemistry-driven research tradition of large pharmaceutical companies has created a major hindrance for co-operation between established corporations and new biotechnology firms and impeded the takeoff of the biotechnology industry (Kaiser and Grande 2001: 39).

The cluster approach makes different demands on innovation policy than does agglomeration policy because clusters depend on linkages between dissimilar companies belonging to different sectors. Changes in framework conditions may be necessary to facilitate conflict solutions. In some cases, it might be necessary to change the competition law to allow more intensive co-operation; in others, property rights may have to be changed to stimulate inter-industrial co-operation. Problems may also occur through regulatory inertia and insufficient standardisation. Concerning the creation of new knowledge, it is important to facilitate interdisciplinary co-operation and interactive knowledge development.

But even more important is to overcome conflicts and confrontations of interests between actors from different industries. This means that the mechanisms leading to inter-industrial co-operation are not of purely economic but also of socio-cultural nature. To bring companies to abandon traditional behaviour and narrow views and to turn into inter-industrial co-operation cultural changes are of crucial importance. It is necessary to offer an environment that allows for the evolution of a common language, social bounds, common norms and view of the world. The innovative milieu approach points in this direction.

8.8. Regional Systems of Innovation

Together with the emergence of knowledge-based industries, competition over technology and growth is shifting increasingly away from competition between nations towards competition between regions. Although due to increasing globalisation and continuous improvements in telecommunications, geographic boundaries no longer affect the availability of information and know-how needed for innovation, this information and know-how is still being generated and used at a local level. In knowledge-based industries, production is initially sited in regions where research is being conducted. Production then attracts further research.

Biotechnology not only tends to cluster regionally, but there are also only a handful of regions in each country that have successfully generated a viable industry. As much of the knowledge produced in new industries such as results from dense interactions between economic actors and therefore remains tacit, geographical proximity is the key factor for an organisation to acquire crucial knowledge. Tacit knowledge refers to knowledge that is intuitive and unarticulated, it cannot be transferred easily because it has not been stated in an explicit form and it can be protected rather easily (Polany 1966, Lundvall and Borrás 1997). The transfer of tacit knowledge takes place in small communities that have face-to-face contact quite often.

Another argument favouring the regional dimension of innovation is the aspect of specialisation. Territories have to specialise and to establish specialised institutional settings in order to be able to offer companies specific advantages and thereby to increase global competitiveness. Together with the change from a resource-based to a knowledge-based economy, natural resources lose their importance as a competitive advantage; instead, territorial advantages and a competitive environment can deliberately be created through establishing a supportive institutional setting.

It is occasionally claimed that region-states are more appropriate in designing a supportive environment for companies to innovate than nation-states. In this context, Ohmae (1993) argues that in an increasingly boundless world the nation-state becomes dysfunctional with the region-state becoming the natural economic zone. Region-states represent genuine communities of economic interest, define meaningful flows of economic activities and can take advantage of true linkages and synergies among economic actors.

A regionally oriented innovation policy, aiming at establishing a strong economic system or trans-industrial cluster, can be found in all four participating countries. However, in most cases, a regional clustering of knowledge-based industry is stimulated by programmes carried out at the national level. In the following, we will discuss the German BioRegio Programme, the Twente Business and Science Parks in the Netherlands, and the Finnish National Centers of Expertise Programme.

In 1995, the Federal Ministry of Education and Research (BMBF) in Germany initiated the BioRegio Programme in order to stimulate the creation of regional biotechnology clusters and thereby the commercialization of scientific knowledge in this field. The political intention behind this strategy was to further strengthening already strong, established locations in this field. As a result, the three winners of the competition – the BioRegions around Cologne (BioRegio Rheinland), Heidelberg (BioRegio Rhein-Neckar-Dreieck) and Munich were already favoured in the 1980s through the establishment of the National Centers of Genetic Research. The BMBF supported 57 R&D projects in 1996–2000 and invested in them some **i** 75 million in total. Only a symbolic amount of public money was invested in the programme assuming that additional funding would come from other sources. The basic idea of the programme had been to demonstrate public support of biotechnological research and to improve the economic conditions for biotechnology companies (Kaiser and Grande 2001).

The definition of the criteria for selecting the most promising regions for the commercialization of biotechnology in Germany clearly originated from the cluster approach. The participating regions had to demonstrate the interaction of different branches of biotechnology research, the existence of supporting service facilities, a regional concept to support biotechnology start-up companies, the provision of financial resources through banks and public equity capital providers, a working structure for the co-operation between regional biotech research institutes and clinical facilities in the region and the capacity of local authorities to effectively decide on applications for biotechnology facilities and field trials (Dohse 2000: 1113).

It is difficult to assess whether or not the programme has been successful, because a systematic evaluation has not been carried out. The fact that public scepticism and resistance against biotechnology has decreased is seen as a major indirect result of the BioRegio Programme. However, as a systematic evaluation of the programme has not taken place, a major precondition for policy learning is missing.

The Twente telecommunications cluster combines a number of institutions with excellent research facilities: the Technical University, the Science and the Business Parks, the Telematic Institute, the Research Department of KPN, and the two hardware suppliers Siemens and Lucent. The concentration and connectedness of firms and universities has provided optimal opportunities for the development of an innovation network. It also helps create a fruitful atmosphere for the development of new start-ups. Students can take part in several programmes that help them develop their own business. If the project has proven its viability after one year, the new entrepreneur can rent a workspace in one of the parks and share financial and administrative services with other start-ups.

The Finnish Centres of Expertise Programme was launched by the Ministry of Interior in 1994 and it received wide government support. Actually other ministries later on joint the programme. The programme is part of the new programme-based regional development work. It is, as the German BioRegio Programme, based on the new approach of regional development, which instead of supporting weak areas focuses on regional strengths and on enhancing and further developing them. The programme is of more catalyst nature, the responsible ministry provides comparatively small financial resources: additional financing is expected to come from cities and municipalities, firms and other sources. The major aims of the programme are:

- to enable the location and development of internationally competitive knowledge-intensive business enterprises
- develop new business activities and establish regional ‘locomotives
- to support regional specialisation processes

- to stimulate co-operation and networking between the key actors involved in innovation activities: universities, research institutes, enterprises (particularly SMEs) and regional authorities.

Like in the German BioRegio Programme, the selection of the centres of expertise takes place through competitive bidding. There are three main categories of selection criteria: quality (research and education, business activities, internationalisation); effectiveness (regional development, national development); and organisational criteria (critical mass, networking, organisation, financing). In the first round, the Government nominated eight regional centres of expertise and, in addition, three sectoral network-type centres. Currently the programme includes 16 Centres of Expertise; among them, six are specialised in the field of telecommunications and six are specialised in biotechnology. The evaluation of the first period of the Centres of Expertise Programme has shown some positive results:

- implementation of regional projects with a total value of FIM 1 billion
- substantial financial support from companies, cities and communities
- creation of 8,000 new jobs and the renewal of 7,000 jobs
- establishment of 290 new enterprises in the centre-of-expertise sectors and of 130 enterprises located in these regions
- participation of 1,150 production enterprises and 300 service firms (low participation rate of SMEs)
- intensive participation of universities and research institutes.

One can have some doubts about whether regions can develop an innovation system comprising all functions and elements that are part of national innovation systems[14]. In general, we can assume that regions add specific institutions and elements to support their specific economic strength. There is much evidence that the growing importance of economic co-ordination at the regional level is caused primarily by a re-configuration of national innovation systems. It is less an indicator for the existence of a fully developed innovation systems on the regional level (Kaiser and Grande 2001). This means that even if we focus on regional developments, relationships between regions and between the regional and national level are becoming crucially important. We have to state the following question: what kind of division of labour between regional and national level is necessary and efficient?

8.9. The European Dimension

One of the major aims of innovation policy is to develop some recognised national or regional advantages by supporting specialisation processes in specific fields of technology. However, countries more or less specialised in specific knowledge fields and production niches cannot produce all the knowledge they use. Specialisation, while contributing to global competitiveness, also creates increasing dependence on knowledge produced abroad. No country is self-sufficient today, particularly in knowledge-intensive industries in which knowledge becomes very rapidly outdated. National or regional specialisation necessarily brings about the need for intensifying cross-border co-operation.

Naturally, big multinational firms have no problem in organising their own innovation networks involving universities, research institutes, suppliers firms, customers and other companies. However, SMEs, smaller universities and research institutes may have difficulties in finding the co-operation partner with the needed complementary knowledge. And particularly in small countries it is often the case that such knowledge is not available within national

[14] This is the more the case the smaller the respective region is. Drawing general conclusions about regions is difficult insofar as they differ significantly with respect to size.

boundaries. These organisations may need government assistance to find the appropriate international partner.

Technological collaboration across borders can be seen as a kind of positive sum game because each country involved receives and provides some expertise simultaneously, although advantages and disadvantages are not always equally distributed among the partners involved. This, however, should not become a hindrance for supporting such international innovation networks. The European Commission is probably the most suited organisation to initiate and support intra-European collaboration. Already now a bulk of financial resources for science and technology has been devoted to foster trans-border collaboration in innovative networks (Archibugi 1999).

The European Commission has conducted several projects to support research collaboration in biotechnology and telecommunication. Biotechnology research and development in biotechnology under the Fifth Framework Programme is concentrated in the key action for “Quality of Life and Management of Living Resources”. In some specific areas the European Commission promotes effective interaction between research organisations and industry. In this sense, the EU encourages applications to cluster their projects involving core centres and associated laboratories in order to create a critical mass and in view of promoting interaction between fundamental and applied research as well as between academic research and industry (European Union 1999).

8.10. Policy Learning

Freeman expressed the idea that by comparing various innovation systems and their institutional structures, we might be able to identify ‘good practices’ and ‘new tools’, which could then be 'borrowed' by other nations to improve their innovative and economic performance (1987). Nowadays there is a growing policy interest in various forms of 'benchmarking' the performance of various institutions, because governments increasingly realise the advantage of institutional adaptation and learning. Due to the huge institutional diversity, institutional benchmarking in Europe is of particular advantage, as the cross-country comparisons of institutional performance is likely to increase the political pressures for individual member countries to address the underlying reasons and causes of poor institutional performance (Soete 2001).

The strict application of the method of benchmarking, however, is hardly possible. In the area of innovation, it is difficult to provide “off-the-shelf” policy prescription (OECD 1998: 106). Particularly in a new emerging and highly dynamic industry it is very difficult to identify isolated good practices. And it is even more difficult to implement a specific institutional solution efficient in one innovation system into another one. Simple institutional borrowing and copying good practices may turn out to be very unsuccessful because the efficient functioning may depend upon the specific constellation of organisations and institutions in which the good practice is embedded. Therefore, the method of benchmarking must be applied very carefully.

A less strict benchmarking - instead of mechanistic benchmarking, we may speak of intelligent benchmarking - on the other hand, may be helpful to better understand one's own innovation system, its strengths and weaknesses. It may give some hints about how to improve the own innovation system (OECD 1998, 107). As Nelson and Rosenberg argue, we may learn from diversity (1993: 2). Based on the above argumentation, we can characterise innovation policy as a process of policy learning (Johnson 1997). “The learning approach, [...], provides a fluid perspective of a policy process in continuous transformation and evolution where no clear stages can be discerned” (Lundvall and Borrás 1997: 64).

The growing importance of policy learning also changes the role of the government in the innovation process. While in the frame of the new innovation policy the significance of technical macro-economic management may decrease and the government may lose control over the dynamics of technological development, the role of the state as a facilitator, supporter and orchestrator of diverse interests remains strong, however. We can talk about a change from direct control to context control, as the state provides the institutional framework for self-organising innovation processes. However, the learning process must be fuelled by organised information collection. Several mechanisms can be established to improve innovation policy learning: policy evaluation, technology assessment, and technological foresight (Lundvall and Borrás 1997). While some of these tools are applied in all four countries, governments neither at the national nor at the regional level have developed into true policy networks which would allow continuous policy learning.

To summarize: innovation policy aiming at developing a new knowledge-based industry needs to be based on a complex conceptual framework, as it is suggested by the systems of innovation approach. As knowledge creation makes up a major part of the idea-innovation chain, policy needs to focus on the earlier stages of the innovation process.

However, innovation policy needs to be changed in the process of emergence of a new industry. As soon as production becomes a major part of the idea-innovation chain, focusing on the production of scientific knowledge only is too narrow an approach; instead, innovation policy has to deal with other systemic failures as well. While it is difficult to make inference about appropriate policy in the view of emerging science-based industries, we can nevertheless draw some policy lessons from our experience.

First, science-based industries such as biotechnology seem to be a regional phenomenon. These industries do not only cluster regionally but in each country there are only a few places, where these new industries can emerge. Second, while new science-based industries often cluster around first-class universities, ancillary or complementary factors must also be available to translate this knowledge into a commercialized product. These factors include the availability of venture capital or other forms of finance, the existence of an entrepreneurial culture, transparent and minimal regulations which do not hinder the start-up and growth process, a larger local market and sophisticated customers, intra- and inter-organisational practices that support information flows and knowledge exchange and a sufficient supply of highly qualified workers (Audretsch 2001, 15). Many of these conditions for success require state intervention and support. Third, it is not enough to establish a setting of support organisations; innovation policy needs to focus more on network formation to guarantee rapid and extensive knowledge exchange, which will benefit regional competitiveness as specialization processes allow for the improvement of knowledge and competence building.

Chapter 9. Conclusion: Time, Space, Policy

Frans van Waarden

9.1. Time: Path Dependency?

The shadow of the past has been present to various degrees in the sectors in our countries. We have found quite a few cases where the path of development of new technologies has been strongly influenced by the industrial and innovation pattern that was already in place in the sector in a specific country, either for the good or for the worse.

In **telecom** the changes that interrupted path dependencies were more radical than in biotechnology. The technological paradigm shift in telecom was followed by major breaks in organizational patterns and regulatory regimes due to the privatization and liberalization policies, which were made possible in part at least by the technological changes, as they destroyed the natural monopoly character of the industry. Such organizational changes did not follow the paradigm shift in biotech. The sector was already a market economy dominated by private firms. Biotech did experience however changes in regulatory regimes, but these went in the opposite direction of those in telecom: less rather than more liberalization.

Furthermore, the starting positions in telecom before the technological paradigm shift were more or less comparable in the different countries. In all countries we found protected domestic markets with a public monopolist PTT (monopsonist on the equipment market) as service provider. The only exception was Finland, which had of old a duopoly on the service provider side: the national PTT for long distance and the regional monopolies for the local networks. As Schienstock argues in his chapter, this duopoly may not have provided for economic competition, it did produce technological competition, which kept the sector on its toes. On the equipment supplier side these was a slight variation between the countries. Though most markets were protected markets with long-time fixed suppliers, the number of suppliers varied. In Germany Siemens had almost a monopoly, and a very cosy relation with the German PTT. The other countries had several suppliers. In Austria the number was the largest, four, organized in the pseudo-cartel KISS (later KASS), but there was really no competition between them as each one’s market share was relatively fixed and subject of collective negotiation. The Dutch PTT followed an intentional policy of having at least two different equipment suppliers, in order not to become too dependent on one. The major one was however Philips. Again Finland differed a bit. Here the technological competition between the duopoly on the service provider side led to some competition between equipment suppliers. Dominant players were however Siemens and Ericcson. These large hierarchies on both sides of the market organized the idea-innovation chains in telecom, which were to some extent nationally segmented, as each national PTT set its own standards. Research was sometimes done by the PTT (as in the Netherlands) and sometimes by the equipment supplier (e.g. Germany).

There were also some differences in the timing of the radical transformations. Austria and the Netherlands were relatively early with deciding to introduce new digital technology, though the speed of realization was relatively low in Austria. Furthermore, there were also differences in the speed of the organizational and regulatory changes. The countries which knew already some competition - Finland among service providers, and the Netherlands among equipment suppliers - were also the first to privatize and liberalize. Apparently they had of old a more liberal current in their regulatory traditions. In Germany and Austria the monopolies persisted longer and organizational and regulatory changes experienced some delay. In Austria the privatization of Austrian Telecom has only just begun.

With the liberalization and opening up of national markets the large country Germany had of course an advantage. Its formerly larger protected domestic market allowed for the development of a large telecom equipment industry, led by Siemens, which had already become world player before the paradigm change. The smaller countries were at a disadvantage. Most of them could not pull it off.

In Austria the organization of the industry did not change much. The typical Austrian corporatist Proporz, already present in the negotiated market share division in KISS, was originally maintained in the early years of digitalization, when the country choose for two different technical systems next to each other (at greater inefficiency and higher costs), the one of Kapsch/Nortel, and the one of Siemens. The domination by foreign firms - originally especially Siemens - was increased after the paradigm change when the two domestic equipment suppliers, Kapsch and Schrack, were taken over by the foreign multinationals Nortel and Ericcson. The country did not manage to profit from the 'window of opportunity' offered by the paradigm change to break the dominance of foreign suppliers and develop its own domestic industry, as the Fins did (see below). While the Finnish story is one 'from foreign domination to global strength of a domestic supplier', the Austrian story is more or less the opposite: 'to stronger foreign domination'. But perhaps the country never had the ambition to change. At least it did not try to. One reason may have been that Siemens Austria was perceived by the Austrian government as somewhat of an Austrian company. This is a curious case of historical path dependency, set off by historical incident. Siemens Austria was nationalized in the first decade after the war, in order to prevent the Russians from carting off the outillage as war spoils - as was done with many other German-owned industries in Austria. (There were many of them, as Hitler had had plans to make the Austrian city of Linz - not far from where he was born - a future world capital of his Third Reich; and as a prelude to that he built a sizable heavy war industry there.) Eventually, the Austrian government returned Siemens Austria back to Siemens Germany, but since the nationalization it always kept considering the company somewhat of a national industry. This is among others apparent from the preferential treatment the company got from the Kreisky government. It is just one case of the increasingly strong economic link to Germany. As more and more Austrian companies have been taken over by German firms recently (most notably the take-over of the CA bank by the Bavarian Hypo-Vereinsbank), Munich has been jokingly called the new capital of Austria. This is an interesting development, given also the rivalry between Prussia and Austria over the domination of Germany - won by Prussia. A new version of 'Heim ins Reich'? One perceives at least here a political and economic familiarity, guiding a specific path dependency.

Neither did the Netherlands profit from the 'window of opportunity'. Perhaps because it tried it too early. The country did have a large multinational that provided telecom equipment, Philips. However, this company tried already to internationalize its telecom equipment position at a time when most European markets were still protected. Philips' joint venture with AT&T, created for this aim, was no success. Differences in organizational culture have been blamed. However, decisive seems to have been the experience that the joint venture could not get a major contract from the French PTT, after Philips had already earlier failed to get access to the Austrian market. This fortified Philips in the idea that as a multinational from a small European country it could not yet penetrate nationally protected markets, even with the technological, organizational, and marketing support from a leading American equipment supplier. The company backed out, and took, as far as telecom equipment was concerned, the strategic decision to concentrate on becoming a supplier of parts for telecom equipment (e.g. chips and lcd-screens), a choice similar to the one it made in the computer industry. Here there was even an explicit agreement between Philips and IBM that the latter would buy Philips chips and that Philips would not enter the market for computers. There is something to be said for this strategic decision. If only that the customers of parts were no national companies which clouded commercial orders with national sentiments. The other major actor in Dutch telecom, KPN, the privatized former Dutch PTT, has tried to become a world player as well. But there are serious doubts about its chances. It is in a similar position as the privatized former telecom service monopolist in Finland, Sonera. Both have barely avoided bankruptcy, squeezed as they currently are between their high debts for buying UMTS state licenses, and the dramatic drop in the value of their stocks.

They probably won't manage to become a world player in telecom services within merging or being taken over by some major foreign firm. However, there have been some minor path induced successes in the country, most notably its relatively good performance in the market niche of telecom cables. It is likely that this is related to the country's leading position in the world in civil engineering, hydraulics, and pipe laying. Unlike Finland, Holland did not manage to profit from its early experimentation and importance of radio communications. In Finland the need for contact with and in the extensive thinly populated north; in Holland from the need to communicate with the colonies in South-East Asia. But in Finland it provided a basis for the later success in mobile communications; not so in the Netherlands.

Among the small countries, Finland is a curious exception. Not because of Sonera, but because of Nokia. One could argue perhaps that this country has profited from being too small and too far away. As such it may not have been noticed for a while by the large incumbent players in telecommunications. And that may have allowed Nokia to develop into the world's leading company in mobile telecommunications, with a world market share of close to 40 percent currently.

Nokia is a case of successful escape from path dependency. Finland had a relatively strong industrial specialization before. Dominant was the industrial cluster around forestry, wood working, pulp and paper, based on the abundance of the northern woods. In addition, its economy was strongly dependent on exports to the former USSR. The country was able to reduce its dependency on this market, and on the forestry industry, by profiting from the 'window of opportunity' offered by the paradigm change in telecom. In a relatively short time it managed to create a major telecom industry - and not coincidentally in the new subsector of mobile telecommunications.

Schienstock offers a number of explanations for the fascinating success of Nokia. In part they boil down to the fact that Finland was able to turn a disadvantage - great distances, thinly populated spaces, a threat of migration from the northern territories to the south-west - into an advantage. These had led to an early development of radio-communications, and when digitalization made a greater density of such communications possible, to an early development of a mobile telecom standard, which subsequently formed the basis of the Nordic standard an later the GSM-world standard.

In addition to these geographic factors there were economic ones, in particular the early exposure to competition. Of old, there had been at least some form of technological competition between the public national PTT and the private local telcos, and hence between their suppliers. Furthermore, Finland was one of the first countries to liberalize the telecom market, when this became technologically easier with the change to the digital paradigm.

Schienstock mentions yet other cultural explanations: The supposed openness of the Fins to modern technology (as indicated by the quick penetration of the mobile phone), the techno-nationalism among Finnish engineers, the presence of entrepreneurship and a global orientation. Though such cultural differences between nations do exist - as anyone who has travelled a bit can testify - they are difficult to measure and that is even more the case for their effect.

More important yet seem to be the traditional close interaction between universities, businesses, and public research institutes, concentrated in a number of regional clusters; and last but not least the concerted and activist technology policy, which not only enhanced the supply of skilled personnel, focused research, and investment funds, but also amplified any entrepreneurial spirit that may have existed already. Typical for this state support may be that Finland was one of the few countries that granted 20-year UMTS-licenses free of charge, a huge indirect form of subsidization considering the enormous prices telecom firms had to pay in other European countries. And which made them subsequently almost bankrupt.

The background behind these concerted and focused public and private efforts to escape from path dependency seem to have been an acute sense of vulnerability and crisis, tipped off by the disappearance of the traditionally important Sovjet export market. It is a bit reminiscent of the strong sense of crisis other small countries with a traditionally open economy, such as the Netherlands, experienced after the second world war and the loss of the economically important colonies in East Asia a few years later. The fear of a return of the high unemployment of the 1930s in the face of the postwar international protectionism combined with the shrinking domestic market led the Dutch to engage in an active industrialization policy, to reduce its dependence on the traditionally strong agricultural, food, and trade sectors. This active industrial policy led to the development of a steel and metalworking industry and helped the expansion of Philips.

Biotechnology is a bit of a different story. It experienced less radical change, if only because the change in technological paradigm was not followed by privatization and liberalization. In so far as there have been regulatory changes, they have gone in the direction of less rather than more liberalization, e.g. stricter rules on testing on genetically modified organisms. Thus it may have been less upsetting for existing path dependencies. However, the differentiation in paths, in industrial and technological trajectories, is greater between our countries. The pre-paradigm change situation in this industry has been markedly different. One reason is that this technology is less specific for one old industry, but can be applied in different traditional industries: agriculture and food, chemicals, pharmaceuticals, environmental care, i.e. green, red and grey biotech. Our countries had a differently strong tradition in these industries. Germany had build up a very strong position in pharmaceuticals, as one of the first science-based industries, on the chemical paradigm of aniline-derivatives (dyestuffs, drugs), since the 19^{th} century. By now it is good for 40 percent of world trade in pharmaceuticals. The Netherlands has for decades if not centuries been specialized on agriculture and food production; and Finland had a strong orientation in forestry and fisheries. Austria had none.

These specializations have clearly influenced the development of biotechnology in these countries. Biotechnology developed from these different bases. Thus German biotechnology developed mainly in the pharmaceutical industry. But it was late in coming. Precisely for path dependent reasons. The organizations, institutions and interests of the German pharma industry were tightly bound to the familiar traditional chemical paradigm of drug development. This made for a certain conservatism. Only when it became clear that biotech offered revolutionary new possibilities of developing drugs they got involved, and, with all the resources they had at their disposal, they managed to catch up. This happened however not without extensive public support for small start-up offshoots from research and academia, which were less burdened by the traditions of the chemical paradigm. The catching up took place first in the safer platform technologies, to gain experience, for start-ups also to earn income; subsequently also in the further stage also in development of drugs for the consumer market, as we can read in the chapter by Kaiser on the German biotech industry.

While German biotech is tilted towards red biotech, the Dutch have a stronger profile in green biotech, befitting the country’s strong orientation in agriculture and food industries. As Oosterwijk writes in his chapter on Dutch biotech, the Dutch sectors of agriculture and food industry had in 1995 a combined annual turnover of 111 billion guilders, which is ... pct. of the GDP. By comparison, the pharma industry had a turnover of less than 5 billion guilders. The country is one of the world’s largest exporters of cut flowers, cheese, butter, milk powder, margarine, beer, pork and chicken meat, tomatoes, eggs, seeds, starch, etc. and has an extensive infrastructure for public and private research on the processing of these food and food derivatives. The Dutch were, unlike the Germans, also relatively early with realizing the possibilities of biotech. Apparently there was less conservatism here. While in Germany the existing path dependent sectoral specialization was a hindrance on biotech development, in the Netherlands is was not. It must be said however that the amount of biotech related turnover in food has remained limited, only 3 percent. But given the size of the turnover, that still amounted to more than 7 billion guilders, more than the whole of the Dutch pharma industry.

The path dependent induced specialization on green biotech turned however out to be to the detriment of the country, and explains why the country has started to lag behind in biotech. Applying biotech in food production turned out to be the more risky business sectgor in biotech. The public is more willing to accept biotechnology in life-necessities like drugs, than in the relatively luxury sector of foods, especially if the innovations do not directly profit the consumer, but the farmer and the environment (higher crop yields, greater resistance to diseases and less need to spray herbicides or use anti-biotics). The best perspectives are perhaps still in food related products that are not directly consumed itself, such as seeds and starch.

Furthermore, the Dutch have a relatively strong showing in grey biotech (environmental care), even though the overall importance of this sector is still small. Here demand played a role. The country is one of the most polluted ones in Western Europe, due to its location at the mouth - where the water flow slows down and the silt settles - of some of the main European sewers, the Rhine, Meuse and Scheldt.

The smaller biotech sectors in Finland and Austria are less strongly specialized. Green biotech is more important in Finland than in Austria, where it has been practically forbidden to use biotech in food production. Both countries have made efforts to develop biotech, but the sectors are still relatively small, in part because there were no big sectors where the industry could build on. In Finland, the large forestry industry would have been a candidate, but apparently there is as yet less need for applying biotech in this sector. Nevertheless, the country tried to repeat the success story of Nokia in this other new major science-based industry: biotech. The success has been limited, bit still greater than in Austria.

This may be related to the differences in effort. In many ways Austria is the remarkable opposite of Finland:

- Finland has embarked on a concerted and activist effort in technology policy; Austria has not done so and has no tradition in it
- Austria has less of an industrial tradition. The industrial heartland of the former Austrian empire were the Chech lands. Its present major industries are a heritage of forced industrialization by the nazis, subsequently nationalized after the war
- There are many complaints about the absence of an entrepreneurial spirit in Austria, while the Fins are proud to have one, supposedly. This may be linked to a difference in mobility of people: relatively high in Finland, even threatening (mobility from north to south-west), but low in Austria
- Austria scores also low in inter-firm cooperation and interaction between universities, business, and public research institutes, while Finland scores high on these indicators

- Finally, Austria missed the sense of crisis which Finland experienced, and which could boost an concerted public and private effort to capitalize on the ‘windows of opportunity’ provided by the paradigm changes in these science-based industries. Its long standing and relatively good economic performance provided less incentives to innovate its industrial base. Curiously enough, the opening of Eastern Europe, which was a threat for Finland - the loss of the Soviet market - provided an opportunity for Austria: Vienna was well located to become a center of supply to many of the - relatively well of, and therefore more attractive - Eastern markets, in Hungary, Slovenia, Slovakia, and the Chech Republic.

9.2. Space: Are there still National Systems of Innovation?

Unlike the concept of ‘national systems of innovation’, as used in the literature on innovation economics, the concept of ‘idea-innovation chain’ as employed in this project has the advantage of being neutral with respect to the spatial dimension of innovative activities. That allows us to problematize the spatial dimension and to treat it as an open empirical question whether idea-innovation chains are (still) located within national systems of innovation.

The paradigm changes have made our two sectors under study into fully international if not global sectors, with many global players. Many of the industries where biotech is being applied, such as pharma, chemicals and food processing, were so already, but now even more. Telecom markets used to be nationally segmented, but technological paradigm changes, privatization and deregulation have broken up these national markets and integrated them in world markets.

The paradigm changes may have provided opportunities for new firms to develop; both sectors are nevertheless dominated by a limited number of world players. The telecom sector by such giants as Siemens, Alcatel, Ericsson, AT&T, Philips (as parts-supplier), Motorola, and - uniquely as large newcomer - Nokia. In biotech applying sectors the world players are firms as Bayer, Hoechst, Novartis, Baxter, or, smaller, lesser known, but dominant in its subsector of starch, the Dutch AVEBE.

These leading firms have a different principle of organization that the political organization of the world. They organize their idea-innovations world wide, both internally and externally, i.e. with lots of suppliers everywhere in the world, that perform functions and subfunctions for their idea-innovation chains. Consumer/user related activities, such as marketing and after sales services, may be, by definition, oriented to the nation where these activities are settled; not so with most of the other stages of the idea-innovation chains. The MNOs have research labs everywhere. Nokia for example has 44 research centers in 12 different countries. These world players locate the research activities in those regions where certain activities are concentrated. Thus Siemens has its internet research activities located in Silicon Valley; but its mobile internet activities in Finland. They work for the whole enterprise. Thus the relatively large research center of Siemens in Austria works for 95% for the head office of Siemens in Munich, that is, for the company as a whole. Similarly, product development, design, or manufacturing are spread around the world, but embedded in the world-wide idea-innovation chains of their company. Using economies of scale and scope, establishments in one country produce a telecom item for many other countries in the world, using technologies and designs developed in yet other countries. .

Thus the international division of labor does not only any more concern final products, with one country producing bananas, and another mobile phones. The international division of labor concerns also the stages in the idea-innovation chains of individual products. The development and design of the mobile phone is done in country A, and the actual manufacturing in country B.

Of course that is not really anything new. It happens already centuries, albeit that the division of labor has turned 180 degrees. Was cotton manufactured 100 years ago in Manchester and Enschede, and the design made near the local markets in India and Indonesia; now the design is done in Western Europe, and the manufacturing in those faar away countries. The rise of labor costs has induced many firms to outsource stages in manufacturing to low wages countries. In the clothing industry of the 1960s, the design and even the cutting of cloth was done in Holland, but the 'assembly', the stitching together happened in Marocco or Romania. After the demise of Dutch shipbuilding, engineering bureaus survived and designed and engineered ships built subsequently in Poland or Brazil.

What is new is that in the idea-innovation chains in science-based industries have been extended and further differentiated, allowing for a greater division of tasks between organizations, also located in different countries. The increasingly complex network structures in the idea-innovation chain are hence often network structures that are spun around the world.

The consequence is that there is often no direct causal link between the various activities of one MNO in a single country. Siemens in Austria has a number of researchers in a research center; and it has a turnover in Austria. But this turnover is not produced by these researchers. The researchers work for the head office, who pays there salary, either directly or indirectly. The Austrian turnover of Siemens concerns the sale of - a.o. telecom - equipment, imported from Siemens establishments elsewhere in the world. It would hence be ridiculous to compare Siemens input (workers, salaries) and output, or to calculate a 'productivity' of the Siemens workers. What holds for the individual firm, may hold to some extent also for the aggregated data of a sector in a specific country.

This is a problem for comparing indicators, traditionally aggregated at the national level. Previous research (Nelson 1993; Lundvall 1992) has focused on three measures of national innovativeness: (i) money invested in research, (ii) number of patents, and (iii) export trade balances for designated high tech areas. But what has not been well appreciated is the fact that these measures are related to different components of the idea-innovation chain. Money invested in research is an indicator of performance in the idea generation phase, patents registered indicate ideas actually generated, even if not (yet) commercialized, and trade balance scores are evidence of the successful commercialization of innovative ideas.

Just as there may not be a causal relation between workers and output, so may there neither been between other indicators of in- and output of the idea-innovation chains. Does it make sense to compare the national expenditure on R and D investments or R and D researchers with the national performance on patents? Often these patents do not reflect the inventiveness of the researchers in that country. MNOs tend to patent in countries where patenting is easier, cheaper, faster, more important, or just where the head office of the MNO is located. Thus Philips patents many of the inventions done by its overseas research centers in the Netherlands. The importance of MNOs in this small country may hence explain the relatively high patent performance of the country.

Political policy measures that are guided by such indicators may misfire. The high patent score of the Netherlands could induce complacency among policy makers; just as the apparently low commercialization could induce nervousness and policy measures.

This brings us to the so-called European paradox, with which this study started: high R and D input, but relatively low output in terms of the production of commercially successful innovations (Andreasen 1995; especially Coriat 1995). Is this not the result of this international division of labor along the idea-innovation chain? Most likely, the R and D is done in Europe, the actual production outside of Europe. That does not mean that the R and D is not successful. It may very well be, but it is not apparent from production/export statistics concerning final goods. Whether R and D is productive is more directly measured by output-indicators of the research stage of the idea-innovation chain, i.e. patents. But as just noted, these have their problems too. The results of the R and D input could also be measured by indicators of the export of knowledge. But do internal transfers of knowledge within one and the same MNO show up in international statistics? Licensing perhaps might. But the exchange of information and tacit knowledge in intra-firm networks of researchers will not.

Is this international division of labor along the idea-innovation chain really a problem for the countries involved? Should the European paradox deserve the nervousness it apparently creates? If the international division of labor in the production of goods is efficient according to the theory of comparative advantages, why would this not hold for a division of labor along the idea-innovation chain? Can countries not increase their wealth by concentrating on research - and employing and paying researchers - even if the final goods made with this research are produced by other countries? Is it not more efficient to do the actual production where wages of manufacturing workers are lower, as in South-east Asia? Or to organize the after sales service in the form of call centers in a country where people are better at speaking foreign languages? Conversely, is a low score on R and D investment necessarily something to be concerned about? Could not a country import and use technology developed elsewhere - either in the form of licenses (as the Netherlands seems to do) or in the form of embodied knowledge in equipment (as Austria does) - and use it to produce value in other sectors, or stages of the idea-innovation chain, such as logistics or marketing? Does every region and country in the world have to do the same, and is hence a low score on R and D something to worry about?

Finally: Should the conclusion be that it does not make sense any more to speak of ‘national systems of innovation’? No, of course not, because there must be a reason why international firms locate certain activities in the idea-innovation chain in some countries and others elsewhere; why companies in Western Europe focus more and more on the beginning and end of the idea-innovation chain; why Siemens maintains a research center in Austria and Nokia concentrates only on research, software production, final product design, and brand management in Finland. Siemens and Nokia do so because both countries still have a good supply of software engineers, and in Austria they are even cheaper than in neighboring Germany. There still is a ‘national system of innovation’, namely those institutions that provide attractive resources - finance, skilled personnel, a favorable legal environment, a good communication infrastructure - for the stages in the idea-innovation chain that produce the knowledge for innovations, even if not the actual innovations in the form of finished products. The complementary ‘system of innovation’ in e.g. Taiwan consists of those organizations and institutions that provide attractive resources for the manufacturing phase of the idea-innovation chain, and that hence induce international firms to outsource manufacturing to independent suppliers or own subsidiaries in that country. In an increasingly knowledge-based economy it may make sense to concentrate on the knowledge producing phases of the idea-innovation chain; to nurture and develop national institutions that attract research, engineering, and design employment - at the front of the chain - and marketing, adjustment to local needs and standards, and after sales service - at the end of the chain - leaving actual manufacturing of the final goods to other ‘national systems of production’.

This is already long what is actually happening. But it would be good if economic policy makers become more aware of it, evaluate these trends, and perhaps give up trying to get complete idea-innovation chains in their part of the world.

9.3. Policy Considerations

The changes in the architecture of the idea-innovation chain, following the paradigm changes, have a number of important consequences for socio-economic policy in general and innovation policy more in particular. We will discuss a number of considerations regarding such policies.

9.3.1. Knowledge in the Private and the Public Domains

The privatization of knowledge, which followed and was amplified by the technological paradigm changes and the attendant liberalization, can have serious long term consequences for the production and diffusion of knowledge and hence for innovation. Of course, the privatization of knowledge, as visible in the increase in numbers of patents and copyrights applied for and awarded, provides a powerful incentive for investment in knowledge. Without a possibility of 'exploitation', there is less incentive for 'exploration'.

However, privatization also has its drawbacks. There are trade-offs to a policy of trade marks. The proprietors of knowledge have a powerful incentive to maintain the temporary monopolies that their patents and copyrights award them. That is, they form a potential powerful force hindering further knowledge development and innovation, at least those kinds that tend to make their knowledge obsolete and their property worthless. Furthermore, the increasing fragmentation of knowledge in a great diversity of private hands could very well frustrate the of creation and development of new products and services which require their combination. If nothing else it could lead to the development of an expensive 'lawyerocracy' (=transaction costs) kept busy with drawing up, monitoring and enforcing contracts, and fighting out commercial conflicts in court. In addition, the privatization of knowledge also puts a brake on its free use and hence may retard its fast and broad diffusion.

Furthermore, the increased commodification of knowledge makes private actors less and less likely to invest in knowledge for the public domain, in the knowledge that their competitors may free ride on their efforts and investments. The problem of collective goods, already present anyway, becomes greater, as the risk of turning out to be a 'sucker', in the terminology of game theory, acquires greater consequences.

The danger is aggravated by the policies that public investors in knowledge are following in this time of increased liberalization and marketization. State agencies are pressing universities and (formerly) publicly funded research institutes to become more commercial: to patent their findings, and to acquire an increasingly large part of their budget from commissions by private business. This implies that these organizations have an incentive to move more towards the production of knowledge that has direct commercial value for the production of new goods and services.

The overall result is that both private as well as public actors are moving away from the production of basic research, of research for the sake of research, which may not have immediately visible commercial applications, but which may turn out to be of great importance for the long-term innovative capacity of industries. One may question hence the wisdom of a public policy forcing (thus far) publicly funded research institutes towards commercialization. Is this not short-termism? Are such forced public-private partnerships not detrimental to long-term innovativeness? Wouldn't it make more sense for private actors to concentrate on investment in applied research and product development; and for public actors to invest more in the production of basic research, to invest in a knowledge infrastructure in the public domain? And hence to reconsider their policies of forced commercialization for universities and public research institutes?

9.3.2. Networking and Competition Policy

As we have argued, the further differentiation of the webs of idea-innovation chains, and the problems with communicating and sharing knowledge and information across market-relations increase the need for close cooperation in networks within these webs. However, this could be hampered by the institution of a strict anti-trust policy. And several national competition policies (among our countries: the Netherlands and Austria) have become stricter in recent years, following the standard set by European competition policy.

Of course on the face of it European and national competition do not seem to do so. National and explicitly European competition policy exempt inter-firm ‘collusion’ (=cooperation) that serves explicit R and D and innovation ends. Article 85 of the Treaty of Rome does so, and following that the Commission has given block exemptions for such forms of cooperation (Drahos 2000). EU competition policy has no problems with inter-firm cooperation that:

- is only explicit collaboration for R and D
- is limited in time
- concentrates on basic, speculative research, more than on commercial development and exploitation
- has no spill over to other issues (in particular quotas and prices)
- where the cooperating firms have only a certain minimal market share

By contrast, European competition policy ‘dislikes’ forms of cooperation that involve:

- profit fixing and sharing
- market sharing
- exclusivity, setting barriers to market entry; involve rules over limiting licensing, and refusal to supply certain firms
- cooperation in the marketing phase

However, this fine-tuning does not solve the tension between the aims of competition and innovation policies. The new realities in technology and private economic governance do not allow for such neat theoretical distinctions. More and more inter-firm cooperation for innovation falls in those categories that competition policy dislikes.

a- the inter-linkage between phases in the idea-innovation chain does not make it so easy to separate basic from applied research and those from product development and marketing. Increasingly, innovation takes place through intensive interaction between the marketing and applied research.

b- In addition, firms are withdrawing from investing in basic research themselves, as this has less direct commercial value. That means that there is less and less need for cooperation just for - so-called pre-competitive - basic or generic research, the only type competition policy is willing to recognize.

c- the differentiation of knowledge, the specialization of firms, and the increased protection of property rights of knowledge make it more and more necessary for firms to cooperate with each other in order to be able to bundle patents for product development. More and more rather specialized firms need to cooperate in all kinds of hybrid and proto-organizations in order to facilitate innovation and product development. Sharing knowledge requires however also a regulation of the sharing of the spoils. No shared exploration without shared exploitation. I.e. joint research and development often requires or leads to some form of regulation of prices, quota’s, market shares, or licensing. This requires also the development of stable long-term relations with some degree of exclusivity. All such elements: exclusivity, barriers to market entry, price and quota regulations are curses in the church for competition authorities.

d- the threat of quicker obsolescence of knowledge, the shortening of product-life cycles, increases the need to earn back investments quicker, and to make arrangements for this. Otherwise the incentive of privatization for investment in knowledge - the raison d’etre of IPR-policy - disappears.

The conclusion: a sound innovation and industrialization policy, recognizing the changes that are taking place in technological regimes, product-life cycles, market structure and economic governance, requires a less strict competition policy. This goes very much against the neo-liberal trend in competition policy. However, the recent EU-white paper on competition policy, planning for a major decentralization of competition policy to the member-states, could facilitate in some cases such a more moderate competition policy regime. It could however also lead to greater differences in this regime between countries. Could this perhaps eventually even lead to a race-to-the-bottom in competition regulation?

9.3.3. Internationalization and National Specialization?

As we have indicated, the differentiation and division of labor within and between organizations in the webs of idea-innovation chains has major international dimensions. Firms and subsidiaries in our countries seem to specialize more and more on phases at the beginning and end of the idea-innovation chains, and they specialize on them: Siemens Austria does research for other Siemens subsidiaries all over the world; and Nokia Finland in mainly active in research, product development, design, and marketing. Most manufacturing is done abroad or is outsourced to companies abroad.

This has significant consequences. Among others it puts into question whether two contradictory paradoxes, with which out project started - the ‘Austrian paradox’ and the ‘European paradox’ - are really policy ‘problems’.

The Austrian paradox refers to a combination of relatively low investment in research and development, but nevertheless good economic performance. The usual explanation of the Austrian paradox has been that the country gets its national earnings not so much from high-tech sectors, but from low-tech, such as tourism. But could such a situation - apart from whether that is really the case in Austria - also not be explained by countries free riding on knowledge developed elsewhere? Is it, given the international division of labor in knowledge production, not thinkable that firms in one countries buy - or otherwise secure - knowledge developed abroad, and exploit it in their own country? After all, a major international electronics company like Philips started its successful history with ‘stealing’ the patent of Edison on the electric light bulb, and manufacturing it in a - then - low wage area as the rural south of the Netherlands? Even if one considers that ‘stealing’ knowledge is not morally acceptable or even legal, a national innovation system could very well rely on buying knowledge developed elsewhere and exploiting it for product development, adjustment of products to local circumstances, marketing it locally, etc. Is there really a need for innovation policy in every country to invest heavily in domestic knowledge production?

Similar question marks could be placed with the opposite so-called ‘European paradox’: a region apparently investing heavily in research and development, but nevertheless reaping not enough fruits of it in the form of the manufacture of new products. While ‘Austria’ might specialize on the exploitation of knowledge produced elsewhere, could ‘Europe’ not specialize on the production of knowledge and selling it to others, c.q. developing products manufactured elsewhere, given the increasing international division of labor. Knowledge has become a tradable commodity in itself, and is the output of webs of idea-innovation chains producing it. European companies are already focusing more and more on the production of intellectual goods: knowledge, information, product development, design, marketing, and leaving actual manufacturing to other countries with workers willing to accept lower wages or having greater manual dexterity. Should industrial/ technology/ innovation policies go against this trend and keep providing incentives for manufacturing in European countries? Should they try to keep complete idea-innovation chains in one country or region? Or should they follow an already ongoing trend and aid the further specialization of European firms on only some phases in the idea-innovation chain? No easy answers here. The trends are contradictory: on the one hand we see an ever greater spatial dispersion of phases in the idea-innovation chain; but on the other hand we see a clustering of industries, and in particular of spatial concentrations of firms active in similar phases of idea-innovation chains: research, development and design in Tampere, Munich, Redmond and Silicon Valley; and production in Singapore and Taiwan. But then: Would such a physical separation of design and manufacturing in the long run not be detrimental, in the sense that feed back from manufacturing to design becomes less easy? It complicates 'jazz improvisation' Japanese style in innovation.

We have questioned the wisdom of some major policy measures: commercialization of public research institutes, a stricter anti-trust policy, an industrial and technology policy focused on keeping manufacturing in our countries. We have even been a bit contradictory in our suggestions: from privatization we derived the need for public investment in basic research; but by questioning the questions around the Austrian paradox we have suggested the opposite: what is wrong with free riding on or buying knowledge developed elsewhere? But then it may not be the task of social scientists to give straightforward cook-book recommendations to policymakers. Their first and foremost task might well be to scrutinize the self-evidencies of policies and policymakers, to expose the inherent contradictions, paradoxes, and trade-offs, leaving the choice to politics.

References

Adjustment Data Base (1998), *Electronic database of welfare indicators* provided by M. Schludi, Max Planck Institute, Cologne, for the project F. Scharpf and V.Schmidt (2000)

Alter, C. and J. Hage (1993) *Organizations working together,* Newbury Park: Sage Publications

Andreasen, L. E., B. Coriat, F. den Hertog and R. Kaplinsky (eds.) (1995) *Europe´s Next Step: Organizational Innovation, Competition and Employment*, London: Frank Cass

Aoki, M. (1988) *Information, incentives, and bargaining in the Japanese economy*, Cambridge/New York: Cambridge University Press

Archibugi, D. (1999) *The Globalisation of Technology and the European Innovation System. Paper prepared for the Maastricht Memorandum on Innovation Policy in a Knowledge-Based Society*, revised version of May 15, 2000, Paris

Archibugi, D. and J. Michie (eds.) (1997) *Technology, Globalization and Economic Performance*, Cambridge: Cambridge University Press

Archibugi D. and M. Pianta (1994) "Aggregate Convergence and Sector Specialization in Innovation", in *Journal of Evolutionary Economics*, 4, May 1994

Arrow, K. (1962) "The economic implications of learning by doing", in *Review of Economic Studies,* 29, 2, pp. 155–173

Audrecht, D.B. (2001) "The Role of Small Firms in U.S. Biotechnology Clusters", in G. Fuchs and G. Kraus (eds) *Small Business Economics, Special Issue: Biotechnology in Comparative Perspective – Regional Concentration and Industrial Dynamics*, 17, 1–2, August-September, pp. 3–15

Balassa, B. (1965) *Trade Liberalization and "Revealed" Comparative Advantage*, in: **???**

Ballard, S., et al. (1989) *Innovation through Technical and Scientific Information: Government and Industry Cooperation,* New York: Quorum

Baltzarek, F. and W. Zipser (1998) "Finanzierungsstruktur und Kapitalmarkt in Österreich seit dem Ende der Monarchie", in *Von der Theorie zur Wirtschaftspolitik - ein österreichischer Weg,* Baltzarek, F., F. Butschek and Gunther Tichy (eds), Stuttgart: Lucius & Lucius

Bayer, K. and F. Hahn (1991) "Wiener Aktienbörse", in *Wifo Monatsberichte*, 5/1991, pp. 291-299, Vienna

Beirat für Wirtschafts- und Sozialfragen (1985) *Finanzmärkte*, Vienna

Bergman, E. M., D. Charles and P. den Hertog (2001) "In pursuit of innovative clusters", in OECD, *Innovative Clusters. Drivers of National Innovation Systems. Enterprise, Industry and Services*, pp. 7-15, Paris

Bierly, P. and T. Hämäläinen (1995) "Organisational Learning and Strategy", in *Scandinavian Management Journal*, Vol. 11, No. 3, pp. 209 - 224

Blakely, E.J., N. Nishikawa, and K.W. Willoughby (1993) "The Economic Development Potential of California's Biotechnology Industry", in *Biotechnology Review* 1, 11–27

Boekholt, P., and B. Thuriaux (1999) "Public policies to facilitate clusters: Background, rationale and policy practices in international perspective", in OECD, *Boosting Innovation. The Cluster Approach*, pp. 381-412, Paris

Brandner, P. (1991) "Kapitalmarkt in Österreich", in *Wifo Monatsberichte*, 11/1991, pp. 633-638, Vienna

Braun, E. (1994) "Promote or Regulate: the Dilemma of Innovation Policy", in G. Aichholzer and G. Schienstock (eds) *Technology Policy: Towards an Integration of Social and Ecological Concerns*, Berlin, New York: Walter de Gruyter Verlag, pp. 95–124

Chandler, A. D. (1977) *The Visible Hand: The Managerial Revolution in American Business,* Cambridge: Harvard University Press

Chandler, A. D. (1990) *Scale and Scope: The Dynamics of Industrial Capitalism,* Cambridge: Harvard University Press

CHI Research (1997) *Table Patents by Sector*, Francis Narin, Haddon Heights NJ

CIS (Community Innovation Survey) (1996 and 1999), Luxembourg: Eurostat

Cohen, S.S. and G. Fields (2001) "Social capital and capital gains. An examination of social capital in Silicon Valley", in M. Kenney (ed.) *Understanding Silicon Valley. The anatomy of an entrepreneurial region*, Stanford, Cal.: Stanford University Press, pp. 190-217

Cohen, W. M. and R.C. Levine (1989) “Empirical Studies of Innovation and Market Structure”, in R. Schmalensee and R.D. Willig, *Handbook of Industrial Organization*, 1989, Volume II, pp.1059-1107: Elsevier Science Publishers, B.V

Cooke, P., P. Boekholt and F. Tödtling (2000) *The Governance of Innovation in Europe. Regional Perspectives on Global Competitiveness*, London/New York

Coriat, B. (1995), “Variety, Routines and Networks: the Metamorphosis of Fordist Firms”,in *Industrial and Corporate Change*, V.4, nr.1

Crouch, C., D. Finegold and M. Sako (1999) *Are Skills the Answer? The Political Economy of Skill Creation in Advanced Industrial Countries*, Oxford: Oxford University Press

Daft, R.L. and R.H. Lengel (1986) “Organisational Information Requirements, Media Richness, and Structural Design”, in *Management Science*, 32, pp. 554 - 571

Debresson, C. (1996) *Economic Interdependence and Innovative Activity. An Input-Output Analysis*, Cheltenham: Edward Elgar

Dohse, D. (2000) “Technology policy and the regions – the case of the BioRegio contest”, in *Research Policy*, 29, pp 1111–1133

Dosi, G. and L. Marengo (1995) “Some Elements of an Evolutionary Theory of Organisational Competencies”, in R.W. England (ed.) *Evolutionary Concepts in Contemporary Economics*, Ann Arbor: University of Michigan Press, pp. 157–178

Drahos, M. (2001) *Convergence of Competition Laws and Policies in the European Community : Germany, Austria, and the Netherlands*, Deventer: Kluwer

Ebers, M. (ed) (1997), *The Formation of Inter-Organizational Networks*, Oxford: Oxford University Press

Edquist, C. (1997a) “Introduction”, in C. Edquist (ed.) *Systems of Innovation - Technologies, Institutions and Organisations*, London: Pinter Publishers, pp. 1–35

Edquist, C. (ed) (1997b) *Systems of Innovation - Technologies, Institutions and Organizations*, London: Pinter Publishers

Eisenhardt, K. M. and B. N. Tabrizi (1995) “Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry”, in *Administrative Science Quarterly* 40, pp. 84 - 110

Ernst & Young (2000) *Biotech in Germany*, Munich

Etzkowitz, H.. and A. Webster, C. Gebhardt, B.R.C. Terra (2000) “The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm”, in *Research Policy 29*, 2000, pp. 313-330

European Biotechnology Innovation System (2000) *Austrian Report on Biotechnology*

European Commission (1993) *White Paper on Growth, Competitiveness, Employment. The Challenges and Ways Forward into the 21st Century*, Brussels

European Commission (1995) *Green Paper on Innovation*, Brussels

European Commission (2000) *Inventory of Public Biotechnology R&D Programmes in Europe*, Luxembourg

European Commission (2001) *The Regional Dimension of the European Research Area*, Communication from the Commission, COM (2001) 549 final, Brussels

European Federation of Biotechnology (1998) *Task Group on Public Perceptions of Biotechnology*, EU-Project 1.12.1998 - 30.11.2000

European Patent Office (EPO) (1997) *Annual Report*, Munich

European Telework Development (2000) *European Information Technology Observatory*

European Union (1999) *Council Decision of 25 January 1999 on adopting a specific programme for research, technological development and demonstration on quality of life and management*

Eurostat (1998) *Research and Development: Annual Statistics 1998*, Eurostat Series 9A

Eurostat (1999) *The Community Innovation Survey 1996* (CIS II), Luxembourg

Finnish Biotech Report (2001), *National Systems of Innovation and Networks in the Idea-Innovation Chain in Science Based Industries*, EU-TSER Project part Finland, March 2001

Fransman, M. (2001) “Designing Dolly: interactions between economics, technology and science, and the evolution of hybrid institutions”, in *Research Policy 30*, pp. 263-273

Freeman, C. (1974) *The economics of industrial innovation*. London: Penguin Modern Economic Texts

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, London: Pinter Publishers

Freeman, C. (1991) “Networks of Innovators; A Synthesis of Research Issues”, in, *Research Policy* 20, pp. 499-514

Freeman, C. (1994) “Innovation and Growth”, in M. Dodgson and R. Rothwell (eds.) *The Handbook of Industrial Innovation*, Aldershot: Edward Elgar

Freeman, C. (1997) “The ‘National System of Innovation’ in Historical Perspective”, in D. Archibugi and B.Å. Lundvall (eds) *The Globalising Learning Economy*, Oxford, New York: Oxford University Press, pp. 24–49

Goldman, C. (1990a) “Die Geschichte der Oesterreichischen Boerse”, in *Wirtschaft und Gesellschaft*, 1990

Goldmann, W. (1990b) “Industriepolitik in Österreich”, in *Wirtschaft und Gesellschaft,* 16/1, pp. 43-63, Vienna

Grandori, A. and G. Soda (1995) “Inter-firm Networks: Antecedents, Mechanisms and Forms”, in *Organisational Studies,* Vol. 16, No. 2, pp. 183 - 214

Granovetter, M. (1982) “The Strength of Weak Ties”, in P. Marsden and N. Lin, *Social Structure and Network Analysis,* Beverly Hills Ca: Sage, pp. 105 - 130

Grant, W. (1996) “'Different EU and US Perspectives on Biotechnology and their Implications for Trade Relations”, in O. T. Solbrig, R. Paarlberg and F. di Castri (eds) Globalization and the Rural Environment, Cambridge:MA: Harvard University David Rockefeller Center for Latin American Studies

Griliches, Z. (1990) “Patent Statistics as Economic Indicators: A Survey”, in *Journal of Economic Literature*, 28, pp.1661-1707

Grupp, H. and U. Schmoch (1992a) “Perception of scientification as measured by referencing between patents and papers”, in Grupp, H.(eds) *Dynamics of science based innovation*, Berlin: Springer Verlag

Grupp, H and U. Schmoch (1992b) *Wissenschaftsbindung der Technik: Panorama der internationalen Entwicklung und sectorales tableau für Deutschland,* Heidelberg: Physica Verlag

Grupp, H. and U. Schmoch, 1995, Science, high technology and the competitiveness of EU countries, Cambridge Journal of Economics (1995), Vol. 19, No. 1, pp. 209 - 223

Hage, J. and C. Alter (1997) “A Typology of Inter-organisational Relationships and Networks”, in J. R. Hollingsworth and R. Boyer (eds.) (1997) *Contemporary Capitalism: The Embeddedness of Institutions,* Cambridge: University Press

Hage, J. and J.R. Hollingsworth (1999) *Idea Innovation Networks: a Strategy for Research on Innovations*, Unpublished Discussion Paper

Hage, J. and J. R. Hollingsworth (2000) “A Strategy for the Analysis of Ideas; Innovation Networks and Institutions”, in *Organisation Studies,* vol. 21, no. 5, pp. 971 - 1004

Hämäläinen, T. (1993) “The Organisational Consequences of Increasing Specialisation and Division of Labour”, in *GSM Working Paper Series,* No. 93 - 25, Newark, New Jersey: Rutgers University

Hämäläinen, T. and G. Schienstock (2001) “The Competitive Advantage of Networks in Economic Organisation: Efficiency and Innovation in Highly Specialised and Uncertain Environments”, in OECD, *Innovative Networks: Co-operation in National Innovation Systems,* Paris: OECD

Herrigel, G. (1998) “Collective Regeneration and Cooperative Self-Blockage: Comparisons of the German, Japanese and American Steel Industries Since the Mid 1970s”, in *Culpepper and Finegold,* 1998

Hertog, P. den, E. Brouwer and S. Maltha (2000) *Innovation in an Adolescent Cluster. The case of the Dutch Multimedia Cluster*, Utrecht: Dialogic

Hofbauer, E. (1990) “Von der Flüsterbörse zur Wunderbörse”, in *Wirtschaftspolitische Blätter*, 2-3/1990, pp. 262-268, Vienna

Hollingsworth, J. R. (2000) *The Institutional Context of Innovation,* presentation held at the Research Seminar of the Finnish National Fund for Research and Development, Helsinki

Hollingsworth, J. R. and R. Boyer (eds.) (1997) *Contemporary Capitalism: The Embeddedness of Institutions,* Cambridge: University Press

Huffschmid, J. (1999) *Politische Ökonomie der Finanzmärkte*, VSA-Verlag, Hamburg

Iansiti, Marco (1995) “Shooting the Rapids: Managing Product development in Turbulent Environments”, in *California Management Review,* 38/1: pp. 1 - 22

Interviews 16**,** Baxter, Intercell, Novartis, 20, 21, from the 150 Interviews of the EU-TSER project Building Bridges Between Ideas and Markets, Dec.1998-Nov.2001

Johannison, B. (1987) “Beyond Process and Structure: Social Exchange Networks”, in *International Studies of Management and Organisation*, Vol. 17, No. 1

Johnson, B. (1997) “Systems of Innovation: Overview and Basic Concepts: Introduction”, in C. Edquist (ed.) Systems of Innovation. Technologies, Institutions and Organisations, London and Washington: Pinter Publishers, pp. 36–40

Jorde, T. M. and D. J. Teece (1990) “Innovation and Cooperation: Implications for Competition and Antitrust”, in *Journal of Economic Perspectives,* 4/3, pp.75 - 96

Kaiser, R. (2001) *Innovation policy in a multi-level governance system: The changing institutional environment for the establishment of science-based industries*. Paper prepared for the conference “European Research Area or National Innovation Competition? Technology Policy in the European and Comparative Perspective” of the Committee on Politics and Technology of the German Political Science Association in Cooperation with the Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe, November 10-11, 2001

Kaiser, R. and E. Grande (2001) *The Emergence of the German Biotech Industry in the 1990s: The Role of the National Innovation System and its Specifications at the Regional Level*, Research Report, Lehrstuhl für Politische Wissenschaft, TU München, September 2001

Kaiser, R. and H. Prange (2001) “Die Ausdifferenzierung nationaler Innovationssysteme: Deutschland und Österreich im Vergleich”, in *Österreichische Zeitschrift für Politikwissenschaft*, 30(3), 2001, pp. 313-330

Kamoche, K. and M. P. Cunha (2001) “Minimal Structures: From Jazz Improvisation to Product Innovation”, in *Organisation Studies*, 22, issue 5

Kleinknecht, A. (ed) (1996) *Determinants of Innovation. The Message from New Indicators*, London: Macmillan

Kleinknecht, A. and D. Bain (eds.) (1993) *New Concepts in Innovation Output Measurement*, New York: St Martin’s Press

Kleinknecht, A., J.O.N. Reijnen and W. Smits (1993) “Collecting Literature-based Innovation Output Indicators: The Experience of the Netherlands”, in Kleinknecht, A. and D. Bain (eds.) (1993) *New Concepts in Innovation Output Measurement*, pp.11-42

Kline, S. and N. Rosenberg (1986) “An Overview of Innovation”, in R. Landau and N. Rosenberg (eds) *The Positive Sum Strategy*, Washington DC: National Academy Press

Kogut, B. (1998) *The Network of Knowledge*, Paper presented at ORSA TIMS, Dallas

Krueger, A. O. (1991) “Economists’ changing perceptions of government”, in *Weltwirtschaftliches Archiv*, 127, pp. 417–431

Landes, D.S. (1969) *The Unbound Prometheus*, Cambridge: Cambridge University

Langlois, R.N. and Robertson, P.L. (1995) *Firms, Markets and Economic Change*, London: Routledge

Lundvall, B.-Å. (ed) (1992) *National System of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers

Lundvall, B.-Å. and S. Borrás (1997) *The Globalising Learning Economy: Implications for innovation policy*, Bruxelles, DG XII-TSER; The European Commission

Lundvall, B.-Å. and S. Borras (1999) *The Globalising Learning Economy: Implications for Innovation Policy*, Brussels

Mannermaa, M. and Ahlquist, T. (1998) “Varsinainen tietoyhteiskunta”, in *Työministeriö: ESR-julkaisut*, 36/98, Helsinki

Mansfield, E. (1986) “Patents and Innovation: An Empirical Study”, in *Management Science*, 32, pp.173-181

Mayntz R: and F.W. Scharpf (1990) “Chances and Problems in the Political Guidance of Research Systems”, in H. Krupp (ed) *Technologiepolitik angesichts der Umweltkatastrophe*, Heidelberg: Physica, pp. 61–83

Meeus, M.T.H., L.A.G. Oerlemans, J. Hage (1999) “Patterns of Interactive Learning in a High-tech Region”, in *Organization Studies*, Vol. 22, Issue 1, 2001

Metcalfe, S. (1995) “The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives”, in P. Stoneman (ed.) *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell Publishers

Metcalfe, S. (1997) “Technology systems and technology policy in an evolutionary framework”, in D. Archibugi and J. Michie (eds) *Technology, Globalisation and Economic Performance*, Cambridge: Cambridge University Press

Metze, M. (1992) *Kortsluiting*, Nijmegen: Sun

Metze, M. (1997) *Let’s Make Things Better*, Nijmegen: Sun

Meyer-Kramer, F. and U. Schmoch (1998) “Science-based technologies: university - industry interactions in four fields”, in *Research Policy*, nr 27, pp. 835-851

Moe, T.(1995**)** “The New Economics of Organization”, in *American Journal of Political Science* 28: 739-777

Myers, S. and D.G. Marquis (1969) *Successful industrial innovation*, Washington: National Science Foundation

Nahapiet, J. and S. Ghoshal (1998) “Social Capital, Intellectual Capital, and the Organisational Advantage”, in *Academy of Management review*, Vol. 23, No. 2, pp. 242 - 266

Narin, F. and E. Noma (1985) “Is Technology becoming Science?”, in *Scientometrics 7*, pp. 369-381

Nelson, R. R. and Rosenberg, N. (1993) “Technical Innovation and National Systems”, in Nelson, R. R. (ed.) *National Systems of Innovation: A comparative study*, Oxford: Oxford University Press

Nelson, R.R. (1987) *Understanding Technical Change as an Evolutionary Process*, Amsterdam: North-Holland

Nelson, R.R. (1988) “Preface” and “Institutions Supporting Technical Change in the United States”, in Dosi, G., Freeman,C., Nelson, R., Silverberg, G., and Soete, L., (1988) *Technical Change and Economic Theory*, London: Pinter Publishers

Nelson, R.R. (ed.) (1993) *National Innovation Systems. A comparative analysis*, New York: Oxford University Press

Nonaka, I. and H. Takeuchi (1995) *The Knowledge Creation Company*, New York: Oxford University Press

Nooteboom, B. (1999a) "Innovation, Learning and Industrial Organisation", in *Cambridge Journal of Economics,* 23

Nooteboom, B.(1999b) *Inter-firm Alliances; Analysis and design*, London: Routledge

Nooteboom, B. (1999c) *Institutions and Innovation Systems: Towards a Theoretical Framework,* Presentation held at the Conference National Innovation Systems and The Idea-Innovation Chain, Wassenaar: January 27 - 29

OECD (1993) *Frascati Manual*, Paris: OECD

OECD (1996) *The OECD Jobs Study: Technology, Productivity and Job Creation,* Volume 2, Analytical Report, Paris: OECD

OECD (1997a) *Science Technology and Industry, Scoreboard of Indicators,* Paris

OECD (1997b) *National Innovation Systems*, Paris

OECD (1998a) *Science, Technology and Industry Outlook*, Paris: OECD

OECD (1998b) *The OECD Jobs Strategy: Technology, Productivity and Job Creation, Best Policy Practice,* Paris: OECD

OECD (1998c) *The OECD Stan Database for Industrial Analysis, 1978 - 1997*, Paris: OECD

OECD (1998d) *Main Science and Technology Indicators*, Vol 2, Paris: OECD

OECD (1999) *Telecommunications Database*, Paris: OECD

OECD (2001a) B. van Beuzekom, "Biotechnology Statistics in OECD Member Countries: Compendium of Existing National Statistics", in *STI Working Papers*, 2001/6. Directorate for Science Technology and Industry, Paris

OECD (2001b), *Science, Technology and Industry Outlook 2001*: Drivers of Growth: Information Technology, Innovation and Entrepreneurship**,** Paris: OECD

OECD (2001c) *Science, Technology and Industry Scoreboard of Indicators 2001: Towards a Knowledge-based Economy*, Paris:OECD

OECD, (1996-2000) National Accounts, Vol. 1, Paris: OECD

Ohmae, K. (1993) "The Rise of the Region-State", in *Foreign Affairs*, 72, pp. 78–87

Ommen, G.J.B. van, E Bakker and J.T. den Dunnen (1999) "The human genome project and the future of diagnostics, treatment and prevention", in *The Lancet*, 354, July 1999, pp. S15

Oosterwijk, H. (2001) *Switching Technology through five decades. Dutch telecommunications under change*, Research Report, Utrecht University, January 2001

Oosterwijk, H. (2003) *Sectoral Variations in National Systems of Innovation. The Cases of Telecommunication and Modern Biotechnology*, Ph. D. Dissertation, Utrecht: Utrecht University

Paija, L. (2001) "The ICT Cluster: The Engine of Knowledge-driven Growth in Finland", in OECD (2001) *Innovative Clusters, Drivers of National Innovation Systems,* Paris: OECD

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

Pavitt, K. (1985) "Patent statistics as indicators of innovative activities. Possibilities and Prospects", in *Scientometrics*, 7, pp.77-99

Pavitt, K. (1994) "Key Characteristics of Large Innovating Firms", in M. Dodgson and R. Rothwell (eds.) *The Handbook of Industrial Innovation*, Aldershot: Edward Elgar

Pavitt, K. (2000) *Innovation Routines in the Business Firm: What matters, what's staying the same, and what's changing?* (Paper for a keynote speech at the meeting of the Schumpeter Society in Manchester on July 1, 2000) SPRU, Science and Technology Policy Research, Brighton UK

Peneder, M. (1999a) "Intangible Investment and Human Resources, The New WIFO Taxonomy of Manufacturing Industries", in *WIFO Working Papers,* 1999, No. 114, Vienna: Austrian Institute of Empirical Research

Peneder, M. (1999b) *Intangible Assets and the Competitiveness of European Industries, An International Comparison,* paper prepared for the European Union, WIFO June 1999

Polany, M. (1967) *The Tacit Dimension*, New York: Anchor

Polt, W. (2001) *Forschungs- und Technologiebericht 2001*, Studie der Arbeitsgemeinschaft TIP im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie und des Bundesministeriums für Bildung, Wissenschaft und Kultur, Vienna: Austrian Research Centers (ARCS), WIFO and Joanneum

Polt, W. et al (1999) *Austrian Report on Technology 2000, Technologie Information, Politikberatung,* Vienna

Porter, M. (1990) *The Competitive Advantage of Nations*, New York: Free Press/Macmillan

Porter, M., and M.B. Fuller (1986) "Coalitions and Global Strategies", in M. Porter (ed) *Competition in Global Industries,* Moston MA: Harvard Business School Press, pp. 315-344

Post und Telegraphenverwaltung (PTV) (several years) *Annual report*, Vienna

Powell, W. (1990) "Neither Market Nor Hierarchy: Network Forms of Organization", in B.M. Straw and L.L. Cummings (eds) *Research in Organizational Behavior,* Greenwich: JAI Press

Prahalad, C., and G. Hamel (1990) "The Core Competencies of the Corporation", in *Harvard Business Review,* May-June: 79-83

Prevezer, M. (2001) "Ingredients in the Early Development of the U.S. Biotechnology Industry", in G. Fuchs and G. Kraus (eds) *Small Business Economics, Special Issue: Biotechnology in Comparative Perspective – Regional Concentration and Industrial Dynamics*, 17, 1-2, August-September, pp. 17–29

PTA (1996) Geschaeftsbericht der Post- und Telekom Austria**,** Vienna

Roelandt, T. J. A. and P. den Hertog (1999a) "Cluster Analysis and cluster-based policy making: an introduction to the theme", in OECD, *Boosting Innovation. The Cluster Approach*, pp. 9-23, Paris

Roelandt, T. J. A. and P. den Hertog (1999b) "Cluster Analysis and cluster-based policy making: the state of the art", in OECD, *Boosting Innovation. The Cluster Approach*, pp. 413-427, Paris

Rothwell, R. (1991) "External networking and Innovation in Small and Medium-Sized Manufacturing Firms in Europe", in *Technovation*, Vol 11, nr 2, pp. 93-112

Rothwell, R. (1994) "Industrial Innovation: Success, Strategy, Trends", in M. Dodgson and R. Rothwell (eds.) *The Handbook of Industrial Innovation*, Aldershot: Edward Elgar

Rothwell, R. and W. Zegveld (1985) *Re-industrialization and Technology*, Harlow: Longman

Sabel C. (1997) "Constitutional orders: Trust building and response to change", in J. R. Hollingsworth and R. Boyer (eds.) *Contemporary capitalism. The embeddedness of institutions*, Cambridge: Cambridge University Press, pp. 154–188

Sabel C., G. Herrigel, R. Deeg, and R. Kazis (1987) *Regional Prosperities Compared: Massachusetts and Baden-Württemberg in the 1980's*, Discussion Paper IIM/LMP87-10b, Wissenschaftszentrum für Sozialforschung, Berlin

Sarmento-Coelho, M. (2000) "Innovation and Quality in the Service Sector: Application to SMEs", in P. Conceição, D. Gibson, M. Heitor and S. Shariq (eds.) *Science, Technology, and Innovation Policy; Opportunities and Challenges for the Knowledge Economy,* London: Quorum Books

Saxenian, A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* Cambridge: Harvard University Press

Saxenian, A. (1996) "Inside-Out: Regional Networks and Industrial Adaptation in Silicon Valley and Route 128", in *Cityscape: A Journal of Policy Development and Research* Volume 2, Number 2, May 1996

Saxenian, A. (1999) *Regional Advantage. Culture and Competition in Silicon Valley and Route 128*, 7th edition, Cambridge/London

Schaumayer, M. (1991) "Währungspolitik und Kapitalmarkt", in *Bank-Archiv*, 4/91, pp. 236-240, Vienna

Schibany, A. and W. Polt (2001) "Innovation and Networks: An Introduction to the Theme", in OECD, *Innovative Networks: Co-operation in National Innovation Systems,* Paris: OECD

Schienstock, G. (1994) "Technology Policy in the Process of Change: Changing Paradigms in Research and Technology Policy", in G. Aichholzer and G. Schienstock (eds.) *Technology Policy: Towards an Integration of Social and Ecological Concerns,* Berlin, New York: Walter de Gruyter Verlag, pp. 1–23

Schienstock, G. (1999) *Interview on Finland*, University of Tampere, Finland

Schienstock, G. and P. Tulkki (2001) *From Foreign Domination to Global Strength: Transformation of the Finnish Telecommunications Industry*, unpublished paper, Tampere

Schienstock, G. and T. Hämäläinen (2001) "Transformation of the Finnish innovation system. A network approach", in *Sitra Reports series 7*, Helsinki: Hakapaino Oy

Schienstock, G., P. Hokanen, A. Lyytinen and P. Tulkki (2001) *From Competing Wires to Controlled Waves. The Idea-Innovation Chain in the Finnish telecommunications sector*, Research Report, Work Research Centre, University of Tampere, March 2001

Shohet, S. and M. Prevezer (1996) "U.K. Biotechnology: Institutional Linkages, Technology Transfer and the Role of Intermediaries", in *R&D Management,* 23, 3

Soete, L. (2001) "The New Economy: A European Perspective", in D. Archibugi and B.-Å Lundvall (eds.) *The Globalising Learning Economy*, Oxford, New York: Oxford University Press

Soete, L. and A. Arundel (eds.) (1993) *An Integrated Approach to European Innovation and Technology Diffusion Policy – a Maastricht Memorandum*, EUR 15090, Luxembourg: European Commission

Soskice, D. (1991) "The Institutional Infrastructure for International Competitiveness: a Comparative Analysis of the UK and Germany", in A.B. Atkinson and R. Brunetta (eds.) *The Economics of the New Europe*, London: Macmillan

Steinmüller, E. W. (1994) "Basic Research and Industrial Innovation", in M. Dodgson and R. Rothwell (eds.) *The Handbook of Industrial Innovation,* Aldershot: Edward Elgar

Streeck, W., J. Hilbert, K. H. van Kevelaer, F. Maier and H. Weber (1987) *The Role of the Social Partners in Vocational Training and Further Training in the Federal Republic of Germany*, Berlin: CEDEFOP

Sydow, J. (1992), *"Strategische Netzwerke, Evolution und Organisation"*, Wiesbaden: Gabler

Thomke, S. and D. Reinertsen (1998) "Agile Product Development: Managing Development Flexibility in Uncertain Environments", in *California Management Review*, 41/1, pp. 8 - 30

TIEKE Information Technology Development Center (1999) *IT Cluster in Finland Review*, Espoo

Tulkki, P. (1996) *State Service or Work for Industry? Engineer education as a social phenomenon 1802-1939*, University of Turku: Research Unit for the Sociology of Education, Reports 38, Turku

Tulkki, P., A. Järvensivu, and A. Lyytinen (2001) *On the threshold of a new technology. Finnish biotechnology industries in the beginning of the 21st century*, Research Report, Work Research Centre, University of Tampere, March 2001

Unger, B. and F. van Waarden (1993) *A Comparison of the Construction Industry in Europe, Characteristics, Governance, Performance and Future Perspectives*, Working Paper of the Vienna University of Economics and Business Administration, No.18/January 1993

Unger, B., S. Giesecke, and S. Rossak (2000) *The introduction of the optical-digital paradigm in the Austrian telecommunications network and the liberalisation of the Austrian telecommunications market*, unpublished report, Vienna

Unger, B., H. Oosterwijk, and S. Rossak (2001) *Austrian Biotech Report*, Research Report, Vienna University of Business Administration and Economics, July 2001

United Nations Industrial Development Organization (UNIDO) (1998) *International Yearbook of Industrial Statistics 1998*, Vienna

Volkskrant (1999) *Finnen zitten het liefst in het zadel*, 4.6.1999

Whitley, R. (1998) *Innovation Strategies, Business Systems and the Organisation of Research*, Paper prepared for the Sociology of Science Yearbook

Whitley, R. (2000) *Divergent Capitalisms: The Social Structuring of Business Systems*, Oxford University Press

Zysman, J. (1983) *Governments, Markets, and Growth. Financial Systems and the Politics of Industrial Growth*, Ithaca: Cornell University Press