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ANNEX I. T1. TELECOM GERMANY

From the Electro-mechanical to the Opto-digital Paradigm: Organizational Change and the Management of Research in the German Telecommunications Sector

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Introduction

The German telecommunications sector has undergone significant changes caused by technological progress and market liberalization. The major technological developments, i.e. the digitalization of communications equipment, the increasing share of software in network technology and the convergence of formerly separated transmission technologies to a universal network technology have reshaped the traditional phases of the R&D process. Basic research lost importance since the most fundamental inventions for today's communications technologies had already been made in the 1960s and 1970s. The use of software required different knowledge and development processes, whereas product life cycles and thus product development phases have been considerably shortened. The liberalization of the German telecommunications market did not only lead to the emergence of new actors in the manufacturing and network operating segment, it also altered the relations between the different groups of actors. On the one hand, universities and non-university research organizations have become an integral part of the manufacturer's R&D process, whereas network operators - as a result of increasing competition and decreasing prices for telecommunications services - either reduced their R&D efforts or they did not even establish departments for research and development. On the other hand, the equipment manufacturers had to cope with lower profits from traditional businesses and, thus, tried to optimize their value-added chain by offering various services especially to new private network operators, such as the design and management of networks.

This report focuses on organizational changes within the German telecommunications equipment manufacturing industry. It will be shown that those companies which managed to react to the new market conditions did so both by internal organizational reforms as well as by establishing new kinds of relations with network operators, competitors in the manufacturing sector and with external providers of R&D services (especially publicly-funded universities and non-university research organizations). Internal organizational reforms were mostly aimed at securing flexibility in large organizations in order to be able to react to fast changing market conditions. Concerning external relations, new forms of interaction became necessary either as the immediate result of market liberalization, which ended long-established extraordinary stable customer-producer relations on the home market, or as a consequence of rapid technological changes, shorter product life cycles and increasing competition on a global scale.

This analysis starts with a short overview of the changes in the institutional environment in which the German telecommunications manufacturing industry is embedded (chapter 1). The most striking features of this institutional change are the emergence of a new regulatory regime, which was the result of market liberalization policies at the national, the European and even the multilateral level, the reform of the German financial system, which gained flexibility through the establishment of an equity capital market, new public policy initiatives which led to an increase of public R&D funds in the field of information and communications technologies, as well as the creation of new relations between companies and the education system which are aimed at reacting to the lack of qualified personnel which is partly due to an inadequate training which does not meet the industry's needs.

Chapter 2 describes how a new constellation of actors emerged on the German telecommunications market as a result of market liberalization, technological change and increasing international competition. Especially in the telecommunications equipment sector, traditional players, which were able to survive under the conditions of a closed national market and institutionalized customer-producer relations, disappeared whereas mostly long-established international equipment manufacturers entered the German market especially in course of the introduction of new technologies for mobile and data communications. In the telecommunications services market segments, the incumbent operator, the *Deutsche Telekom AG* (DTAG) became confronted with a growing number of competitors. However, until today, the *DTAG* has been able to maintain significant market shares at least in some service market segments.

In chapter 3 we concentrate on the question of how organizational relations have changed. These changes have occurred at least at three different levels. Firstly, as a result of decreasing institutional funding for corporate R&D facilities as well as for publicly-funded R&D organizations, relations between the manufacturing industry and the public research system are today more market coordinated. Publicly-funded R&D organizations became an integral part of the corporate innovation process. As a result, a R&D market has emerged in which corporate R&D units compete directly with external providers for research and development funds. Secondly, given the fact that production life cycles have been considerably shortened, inter-firm relations is today's dominant mode in technical standardization. Companies cooperate with competitors in standardization fora either in order to reduce market uncertainty or in order to strengthen their position by introducing own developments in industry-wide standards. Thirdly, in a liberalized market environment, producer-customer relations changed significantly. Equipment manufacturers had to re-define their relations with the incumbent operator and they had to establish new kinds of relations with private operators which entered a market which requires high initial investments.

Corporate actors did not only re-define their external relations, but also introduced far-reaching internal organizational reforms which were aimed at gaining flexibility considered crucial under the new market conditions. In chapter 4, we identify four areas of organizational reform. The introduction of knowledge management procedures occurred in order to make existing knowledge more productively available within the organization. Newly established product- and innovation management procedures were aimed at foreseeing new technology trends in the companies' core business segments which than have to be transferred into the innovation process. The creation of quality management procedures has taken place mostly in order to optimize relations among different corporate units as well as between the companies and their customers or suppliers.

1. The changing institutional embeddedness of the liberalized German Telecom-munications Sector

1.1 The new regulatory framework: The liberalization of the German Telecommunications market

The regulatory framework of the German telecommunications sector has been transformed completely since the late 1980s. In accordance with European legislation on telecommunications liberalization as well as agreements made in the context of the *World Trade Organization (WTO)*, the legal framework of the German telecommunications sector was reformulated in three steps.

The first significant change in the legal framework of German telecommunications since the 1920s occurred in 1989 with the enactment of the "Poststrukturgesetz", which led to a separation of the posts and telecommunications administrations, the separation of regulatory and managerial functions, the re-organization of the Deutsche Bundespost, and the liberalization of value-added services and of customer premises equipment. The "Postneuordnungsgesetz", enacted in summer 1994, was the second major change in the legal framework of German telecommunications. The law established the legal preconditions for the privatization of the *Deutsche Bundespost* by reformulating Article 87 of the constitution (Basic Law) and by changing the legal status of the public network operator into a public limited company. As a consequence, 25 percent of the Deutsche Bundespost Telekom were sold in November 1996; a second and third tranche in summer 1999 and summer 2000. The "Telekommunikationsgesetz", enacted on January 1, 1998, completed the liberalization of the German telecommunications market and established a new regulatory regime for the industry. In detail, the law abolished the existing monopolies for the telecommunications network and the basic voice telephone service, dissolved the federal ministry for posts and telecommunications, and established a new, independent regulatory authority for the regulation of the posts and telecommunications markets.

As a result of these legal changes, within a decade, the German telecommunications sector has been completely transformed from a public monopoly to a regulated market. However, this is not to say that telecommunications have become a commercial activity like any other. In the new Article 87f of the Basic Law, the government has reemphasized the state's duty to guarantee a universal telecommunications service. As a consequence, rather than replacing the state by the market, a new regulatory framework has been established. The basic functions of regulation in telecommunications are to produce properly functioning markets on the one hand (economic regulation) and to safeguard the provision of telecommunications as a public good on the other hand (social regulation).

The regulatory approach employed in the German telecommunications sector is characterized by a strong emphasis on economic regulation with the goal to create and to intensify competition in all sectors of the telecommunications market. Moreover, comparatively little problems emerged with social regulation, since the liberalization of the markets and the privatization of the public network operator has not resulted in some of the negative side-effects observed elsewhere (e.g. a lowering of the quality of services, delayed fault repair, pay phones out of work etc.). The most obvious result of the new regulatory regime in German telecommunications is a significant intensification of competition. A large number of new service providers, most of them offering call-by-call services at low rates, have entered the market. Competition has resulted in considerable drop of tariffs. For domestic long-distance calls, some tariffs are 85 percent lower than before liberalization; for international calls, tariffs are 74 percent cheaper on average (on the ten major routes). The consequences for the incumbent network operator and its suppliers have been significant cost pressures and a remarkable decline of prizes for equipment.

1.2 New ways of financing innovation: The reform of the German financial system

In the 1990s, the reform of the German financial system occurred mostly by the establishing of an equity capital market which led to an tremendous increase in the availability of venture capital and the establishment of a high technology stock market segment, the *Neuer Markt*, at the Frankfurt stock exchange. The availability of venture capital did not only improve the conditions for innovative start-ups in the communications industry, it also allowed already established actors to support spin-offs from their own organization or to establish strong ties to innovative small and medium-sized companies which started a business of strategic importance for the established market actor.

In 1999, *Siemens* established a legally independent company, the *Siemens Venture Capital* (SVC), with an initial capital stock of € 200 million. *SVC* invests in start-up companies and venture capital funds in the U.S. (60 percent), Europe (25 percent) and Israel (15 percent). Investment in start-up companies is always limited to a minority holding of three up to thirty percent. Companies, in which *SVC* invests, are obliged to realize a rate of return of at least 25 percent which is necessary to cover SVC's capital costs. In September 2000, *SVC* had invested the initial capital of € 200 million in 26 venture capital funds and 20 start-up companies. These companies were selected out of a total number of more than 2,000 projects which had applied for a *SVC* capital investment. Looking at direct investments of *SVC* it becomes clear that *Siemens* provides venture capital to a large extent to companies which are engaged in communication technology, especially in network- and internet technology.

In October 1997, *Deutsche Telekom AG* established its own corporate venture capital subsidiary, the *T-Telematik Venture Holding GmbH* ("T-Venture") with an initial capital stock of DM 100 million. With the creation of *T-Venture*, the *DTAG* has expanded its business activities into the financial service market since T-*Venture* is obliged to operate profitable. The primary goal behind the provision of venture capital therefore is to realize profits out of its capital investment by accompanying start-up companies until their going public. Apart from that, the *DTAG* gains access to innovations and technological developments of start-up companies which operate in the strategically important TIMES markets. In 1999, *Deutsche Telekom* increased *T-Venture's* capital stock to € 153 million and started operations in the U.S. by establishing *T-Venture of America Inc*., located in the Boston area as well as in Silicon Valley. Since its creation, *T-Venture* invested in about 40 companies which were selected out of more than 1,000 firms considered for the provision of venture capital.

Venture capital activities can not only be found in private industries but also in the public sector, both at the federal as well as the subnational level. *Bavaria*, for example, founded the "*Bayern Kapital Risikobeteiligungs GmbH*" in 1995 and has since spent more than 115 million DM for financing 84 start-up companies which are engaged in biotechnology, software/multimedia, and medical technologies. At the federal level, the *Ministry of Economics* (BMWi) started a program ("Beteiligungskapital für kleine Technologieunternehmen", BTU) in 1995 which mobilizes venture capital especially for small technology companies. In close cooperation with private VC companies, the BTU program was able to provide roughly 1.5 billion DM in 1999 only (BMBF 2000: 204).

In 1997, the *Deutsche Börse AG*, launched a new trading segment at the Frankfurt Stock Exchange which is specialized in small technology companies. Only three years later, around 270 companies are registered to the New Market ("Neuer Markt", NEMAX), many of them are active in the wider segment of telecommunications services and technologies. The NEMAX sector index for telecommunications, however, consists of only 15 companies which are primarily engaged in voice communication services as well as related equipment or software solutions. Many more companies which are primarily active in the field of data communication services and equipment, such as *T-Online*, *QS Communications AG*, or *ADVA AG* are listed on several other sector indices such as NEMAX Internet or NEMAX technology.

1.3 Information and Communication Technologies as a field of strategic technology promotion: public R&D programs at the subnational, federal and European level

At the national level, the federal government started to support research and development in communications technologies in 1978 with a program called “Technische Kommunikation” which expired at the end of the 1980s, when the *Federal Ministry of Research and Technology (BMFT)* decided to significantly reduce its R&D funds for telecommunications research and development. In view of the liberalization of the telecommunications market, it was the perspective of the *BMFT*, that the incumbent operator should be motivated to engage more in R&D funding, since the *Deutsche Telekom* invested a considerable smaller share of its turnover in R&D than other network operators, such as *France Telecom*, the *British Telecom* or *NTT* (Grande/Häusler 1994: 159 f.). In the 1990s, however, the Research Ministry (now: the *BMBF*) re-engaged in the promotion of R&D in telecommunications as part of its overall strategy aimed at encouraging the development and use of modern information and communications technologies for the information society. Within this context, the *BMBF* provides financial support for research and development especially on basic communications technologies, i.e. mobile multimedia communications systems (Project: “MobiKom") and optical communications networks (Project: "KomNet"). The *BMBF* further increased its funding for the period 1999-2000. The total budget amounts to about 1 billion DM per year especially due to a disproportional rise of federal funds in the areas of multimedia and informatics. Funding for basic communication technologies as well as micro technologies and production technologies remained relatively constant. However, most funds – roughly a third of the total budget in information technologies – are still delegated towards research and development in basic communication technologies.

At the subnational level, the German states support R&D in telecommunications both through the institutional funding of universities and the co-funding of non-university research organization, but also by own R&D programs aimed at promoting use and development of information and communication technologies at the regional or local level. The states of *Baden-Württemberg* and *Rhineland-Palatinate*, for example, established a joint research program in advanced media technologies in 1992 which promotes, among other things, the development of multimedia access networks. Between 1997 and 2001, both states will provide about 25 million DM of which 70 percent will be given by *Baden-Württemberg*. *Bavaria* has initiated two programs, "*Offensive Zukunft Bayern*" in 1994 and "*High-Tech Offensive Bayern*" in 2000, which are aimed at investing more than 8 billion DM from privatization of former state-owned companies in modern technologies. The programs are focused on five technology areas: life sciences, communication technologies, material sciences, environmental technologies, and mechatronics (BMBF 2000: 226).

In the early 1980s, the *European Community* became active in the field of telecommunications, too. The establishment of an European telecommunications policy was motivated primarily by the belief that the development of the information and communications technology industry would be crucial for Europe's competitiveness. Since the first European programs in communications technologies, *ESPRIT* and *RACE*, funding R&D in this field has increased steadily. In the fifth framework program (1998-2002), the *European Commission* annexed its research funding in the area of information and communications technologies with the EU's overall strategy for the creation of the information society. Accordingly, the fifth framework program provides

"user-friendly information society" (IST). This program promotes activities aimed at improving the usability, dependability, interoperability and affordability of technologies and applications for the information society. With more than 20 percent of the total budget, the IST program is by far the most important single action of the fifth framework program.

1.4 Human Resources Management: new forms of interaction between companies and the training system

Although the German educational system has often been criticized especially because of the fact that "education and training at schools and universities lacks practicality, lasts too long, and is therefore in need of improvement" (BMWi 1999: 7), the quality of university education is obviously advantageous for the competitiveness of the German R&D system. However, given the very low growth rate of graduates in natural and engineering sciences, Germany is facing a significant lack of qualified personnel in both areas. As for foreign equipment manufacturers which have entered the German market in the 1990s, the know-how and the skills of the university-trained personnel has been, besides the projected dynamic of a liberalized telecommunications market, the decisive factor for the establishment of R&D facilities in Germany. However, there are certainly also weaknesses, such as the lack of experience of graduates to work in (international) teams as well as the tendency of academic education to impart very specialized knowledge. Since most equipment manufacturers have organized R&D in integrated projects in which 100 to 600 employees from different international locations can be involved, team work ability is crucial. Besides that, many equipment manufacturers encourage their employees to work for at least one or two years in a foreign R&D unit. At *Nokia*, for example, about 10 percent of the German personnel work at foreign R&D locations, whereas reciprocally 10 percent of the positions in Germany have been regularly occupied by foreign *Nokia* R&D employees. Moreover, since technological progress in the telecommunications sector takes place at high speed and the complexity especially of today's software applications is increasing, equipment manufacturers are in need of highly qualified personnel with methodological know-how at their disposal, whereas the demand for specialists is relatively low. Even if qualified personnel is available, it takes the telecommunications equipment manufacturing industry at least 6-12 months before new employees can be fully integrated into R&D projects.

Therefore, the need for an active human resources management is the main reason for close, and sometimes exclusive, relations between the equipment manufacturers and certain university departments. By sponsoring diploma or doctoral theses or by co-financing university research projects, equipment manufacturers seek to ensure that universities keep pace with the market developments. When recruiting R&D personnel from universities, the firms have developed different strategies to integrate the employee in the company's R&D system. At *Siemens*, for example, most university graduates from technical disciplines first work in the Corporate Technology Center before they are employed in R&D laboratories of the business divisions.

2. Globalized Markets and Technologies: The new Actor Constellation on the German Telecommunications Market

As a consequence of the liberalization of the German telecommunications market, an immense number of companies have been established in the field of telecommunications services. The number of equipment manufacturers, however, has remained relatively constant over the last twenty years; although, especially in the field of full service equipment manufacturers, traditional companies have disappeared while new firms - mostly long-established foreign suppliers - have entered the German market.

2.1 Dynamic growth in the market for telecommunications services

In terms of telecommunications services, after the abolishment of the monopoly on voice telephony, there were more than 100 companies offering voice communications services over fixed-lines in

Germany. About 60 firms have established their own networks enabling them to offer their services at least partly independent of the infrastructure of the *DTAG*. The other 40 companies are resellers who lease lines from the network operators (WIK 1999: 7 ff.). In the first year after liberalization of voice telephony services, the *DTAG* could preserve its market dominance. In terms of turnover, its market share in the long-distance segment was 92,5 percent, in the local segment 99,5 percent. Only 0.3 percent of all private telephone lines have been connected by private network operators (WIK 1999: 9). In mobile communications, 17 companies provided services on the German market in mid-1999. Four of them, the *DTAG* (T-Mobil), *Mannesmann Mobilfunk (now: "Vodaphone D2")*, *E-Plus*, and *VIAG Interkom*, were granted licenses for digital mobile communications. They offer their services over own networks. The other 13 firms are resellers who are independent of individual licensees. In mobile communications, the actors who were first on the market are still the dominant companies. In August 1999, the *DTAG* and *Mannesmann Mobilfunk* had a combined market share of 83 percent (WIK 1999: 24 f.). In terms of data communications, the number of internet-users quadrupled between 1996 and 1999 to more than 11 million, and more than 1,000 firms offer access services. However, roughly half of all internet-users are clients of one of the four major access providers: the *DTAG* (T-Online), *AOL*, *CompuServe*, and *Germany.net* (WIK 1999: 32 f.).

2.2 The Internationalization of the German telecommunications equipment sector

As for telecommunications equipment manufacturers, the number of companies engaged in this sector amounts to 130, of which three fourths are small and medium-sized companies. As in the 1980s, the number of manufacturers which produce full-service communications systems - switching equipment, transmission equipment, access systems, and terminals - is considerably smaller. However, traditional equipment manufacturers on the German market have disappeared, whereas mostly international manufacturers have entered the market either by overtaking established "national" firms or in course of the introduction of new communications technologies. Today, the major corporate actors are on the German market are *Siemens*, *Alcatel SEL*, *Bosch* (until 1999, when the company sold its public network business segment to *Marconi*), *DeTeWe*, *Ericsson*, *Nokia*, *Nortel* and *Lucent Technologies* Moreover, as a result of the ongoing convergence of voice and data communication networks, both in the fixed-line and mobile segment, *Cisco Systems* gained importance as an actor on the German telecommunications equipment market. *Ericsson* and *Nokia* increased their engagement on the German market in course of the introduction of digital mobile communications at the beginning of the 1990s, whereas *Lucent Technology* entered the market after having overtaken the German business of the former alliance of *Philips* and *AT&T. Nortel* stepped into the German market by engaging in a joint venture with *DASA*, a subsidiary of *DaimlerChrysler.*

All these equipment manufacturers conduct research and development in Germany, however, they are very different in terms of their R&D capacities. On the one hand, *Siemens* and *Alcatel SEL* which are two of the largest telecommunications equipment manufacturers in the world and which have dominated the national market for decades, have - for obvious reasons - far more R&D personnel and financial resources at their disposal than the newcomers to the German market, such as *Lucent Technologies, Ericsson, Nokia, or Nortel*. On the other hand, these newcomers are very active in expanding their R&D capacity in Germany. In their view, Germany does not only provide a highly qualified R&D work force, but has also developed into one of the most dynamic telecommunications markets in the world as a result of liberalization.

3. The Market as the dominant mechanism of coordination: Organizational Relations in the German Telecommunications Sector

The liberalization of the German telecommunications market did not only alter the composition of the sector through the entrance of new corporate actors, but also changed considerably the ways and means how different actors interact with each other. This holds true especially for relations aimed at cooperating in research and development, for inter-firm coordination in standardization and mostly for the relations of equipment manufacturers and service providers.

3.1 The Emergence of a R&D Market in German Telecommunications

Market liberalization as well as rapid technological progress have led to the establishment of an R&D market within the German telecommunications sector. This market is comprised of internal research and development departments of the private sector industry as well as universities and public research institutes. The most striking feature of this R&D market is that all these actors are increasingly integrated into the innovation process in telecommunications; however, internal and external R&D facilities differentiate themselves in terms of their respective functions within the innovation process. Universities as well as the companies’ research departments are still more occupied with longer-term, pre-competitive R&D which has a time span of three to five years (sometimes even ten years); whereas the companies' development facilities as well as public research organizations operate within a time perspective of one to three years, sometimes even shorter. Since both the equipment manufacturing industry as well as the national government have reduced their institutional funding, all actors of the R&D market have to an increasing extent to compete with each other for industrial contracts and public funds.

Especially public research organizations, such as the *Heinrich-Hertz-Institute* or *GMD FOKUS*, have adjusted to this new market environment by implementing marketing and quality management programs. They are today more engaged in patenting or licensing their R&D results than in the past. Universities offer not only R&D services, but also highly-qualified personnel. For that reason, private sector industry is engaged in cooperation with universities, chiefly by supporting diploma and doctoral theses. In many cases, students are able to work on similar projects within the industry after graduation. Most equipment manufacturers prefer project cooperation with neighboring universities or with highly specialized university departments. In the latter case, geographical distance is not an obstacle to cooperation. In view of network infrastructure technologies, *Siemens*, for example, relies mostly on departments at the *Technical University of Munich*, whereas projects on mobile communications have been conducted with the *University of Kaiserslautern*. Moreover, *Siemens* has established relations to foreign universities, such as the *Carnegie Mellon University* or the universities of Madrid and Barcelona.

If the private sector industry engages in project cooperation with publicly-funded research organizations, the problem of project funding and of intellectual property rights ownership are the most important ones. Many equipment manufacturers, such as *Siemens*, *Alcatel SEL*, *Nokia* or *Lucent Technologies* cooperate with university departments under the conditions of exclusivity and full ownership of patents and licenses. *Siemens* and *Alcatel SEL* only engage in projects which are financed equally by the firm and by public R&D funds. In terms of longer-term research, private sector industry also observes university activities and - in case of interest for the firm - acquires university patents. Universities, in return, have established specialized departments for technology transfer in order to better marketing their research results.

The analysis of authorship of scientific papers can give an indication to what extend companies cooperate in R&D and who are the preferred partners. Having explored the number of collaborative research papers of large enterprises in the equipment sector between 1993 and 1996, *Tijssen/van Wijk* can show that *Ericsson*, and especially *Siemens*, cooperated mostly with external domestic public institutions (27 percent and 46 percent, respectively of the co-authored papers), whereas the majority of papers (29 percent) which were written by *Alcatel*'s employees had a co-author from within the company. All three companies share the commonality that collaborative research papers linked them mostly with public or private organizations within the EU; co-authored papers with institutions from outside Europe amounted to a maximum of 9 to 15 percent (1999: 532).

All in all, the reorganization of the manufacturers' R&D organization has been the major precondition for the emergence of an R&D market. *Siemens*, for example, shifted many development activities to the business units which conduct development work in more than 30 countries. Research, however, is still concentrated mainly at the telecommunications lead-markets in the United States, Great Britain and Germany. In terms of financing, the corporate technology department lost most of its institutional funding and has thus become exposed to competition. In 1994, about 70 percent of the total budget still came from central funds, 15 percent from the business units, and 15 percent from public R&D funds. Today, the share of institutional funding of the corporate technology department is only 35 percent (which is only five percent of Siemens' total R&D expenditures) with the consequence that the research department is forced to acquire about 60 percent of its annual budget from Siemens' corporate business units and 5 percent from public R&D funds. In this respect, *Siemens'* corporate business units enjoy the advantage of competition between internal and external research organizations, whereas the corporate technology department has become better integrated into the firm's businesses, since it has to offer R&D services which enhance the position of the business units in a competitive market environment.

3.2 Inter-firm cooperation as the dominant mode in standardization

The influence of the manufacturing industry on standardization in telecommunications increased parallel to a development marked by growing competition and shorter innovation and production cycles within a competitive environment. In contrast to the electromechanical era, standards are now more often developed "at the same time as the application of the technologies to which they refer, or even in advance of the application of these technologies" (Hawkins 1992: 342). Especially in regard to recent developments in telecommunications technology, it seems hardly possible for international standardization organizations to keep pace with industrial efforts to define technical specifications for new products. Hence, the equipment manufacturers have become the key players in standardization either through licensing their products to competitors or through collaborative action within the framework of industrial consortia. By licensing their products, manufacturers are not only able to broaden the basis for their self-developed standards, they also have at least some control over the market prices of the respective products. Therefore, manufacturers are very engaged in licensing, though companies are used to granting licenses only after a certain period of time (at least one year after introduction of the product) in order to keep their competitive advantage.

Additionally, telecommunications equipment manufacturers are increasingly engaged in standardization through collaborative action within industrial consortia. Consortia have been defined as informal alliances that are financed by membership fees for the purpose of coordinating technological and market development activities (Hawkins 1999: 161). For Hawkins, industrial consortia consider their efforts to define standards as only one part of their more general aim to coordinate technology with emerging market demands. Their "desired final product is a coordinated segment of the ICT market place. The consortia objective is to use technology to create business communities" (1999: 162). Examples of consortia in the telecommunications industry are: the ADSL-Forum, the ATM-Forum, the UMTS-Forum, the Networks Management Forum, and the Telecommunications Information Networking Forum (cf. Hawkins 1999: 165).

3.3 Market Liberalization and the emergence of new producer-customer relations

The liberalization of most telecommunications markets in industrialized countries has significantly changed the conditions under which equipment manufacturers market their products on domestic and foreign markets. In view of the German situation, especially since 1998, foreign equipment manufacturers have entered a market which was previously dominated by only a small number of institutionalized suppliers of the former DBP. Whereas this former, and by-far most important, customer of the equipment manufacturing industry was faced with competition from various new network and service providers which differed significantly in terms of size and product portfolio, the end-user segment has become more and more heterogeneous, demanding differentiated services (cf. Jung 1998: 30 ff.). Moreover, whereas all network and service providers are under increasing pressure from price competition, the new entrants into the telecommunications services market differ much from the incumbent in terms of their financial situation, since heavy investments were necessary before services could even be offered. As a consequence, the coordination of equipment manufacturers and network operators, which was based on formal and informal agreements has been replaced to a significant extent by market mechanisms. On behalf of the equipment manufacturers, this has led to considerable changes in their strategies and activities:

- *Firstly*, telecommunications equipment manufacturers can no longer rely on medium- or long-term investment plans by a monopolistic PTT, but they have to deal with operators who invest in their networks according to actual needs.

- *Secondly*, because of the financial situation of most customers, manufacturers do not only have to provide technical solutions, but also financing plans (Jung 1998: 31).

- And *finally*, in contrast to the electromechanical era, in which the PTT procured equipment according to its self-defined technical description, today, equipment manufacturers are obliged to offer their customers innovative technological systems which very often combine solutions for voice, data or mobile communications.

Equipment manufacturers have found various methods to support private network operators in finding a financial solution which allowed them to procure the network infrastructure: the "pay as you -model provided the operator with a network infrastructure which was designed for more users than the client actually had at that moment. In this model, the operator could invest on the basis of an installment plan depending on the number of users of its network. Another model was the "Build-Operation-Transfer" model in which the manufacturer operated the network himself until the profits equalized the costs for the network. In a third model, named "risk and revenue sharing"-model, the manufacturer is engaged, for the duration of the investment plan, in an informal joint-venture with the network operator. On demands of private network operators, telecommunications equipment manufacturers have added various services to their value chain by not only offering the development and production of network components, but also the network design, installation and management. The market for these services is rapidly expanding with annual growth rates of about 30 percent with some of the equipment manufacturers.

For the former institutionalized suppliers, the establishment of new network operators has been highly ambiguous. On the one hand, the new operators promised to create a new market and additional supply opportunities; on the other hand, the business relations with private network operators proved to be critical shortly after liberalization, since most of the private operators considered them as closely associated with the former PTT, whereas the incumbent operator was suspicious about the engagement with a private competitor. In this situation, the former institutionalized suppliers recognized that *trust* and *trustworthiness* was crucial for business with both market actors. In order to secure trustworthiness, organizational safeguards to guarantee confidentiality have been introduced, for example by separating the key-account managing divisions in order to prevent that one customer's information about investment plans being given to another. This does not mean that equipment manufacturers are not interested in strategic alliances with individual network operators. On the contrary, in cases where they have agreed to such an alliance, network operators can acquire systems with specific technical features with a guarantee of exclusiveness for at least one year.

As a result of market liberalization, business relations between the *DTAG* and its former institutionalized suppliers also changed significantly. The most striking difference certainly is that the *DTAG* ended its traditional procurement policy which was the basis of the close relationship during the electromechanical era. Today's relationships are characterized by significantly decreasing investments of the *DTAG* since digitalization of the German telecommunications infrastructure was completed by 1997. Nevertheless, at least in the market segment of digital switches, *Siemens* and *Alcatel SEL* are still the main suppliers. The *DTAG* still coordinates the respective market shares of both manufacturers even if the decisions to procure one of the two systems fall in the competence of its regional procurement divisions. Therefore, even if there is competition at the regional level, an informal coordination of market shares at the central company level limits that competition considerably.

4. Organizational Innovations and the Management of Innovation in the German Telecommunications Sector

In the 1990s, equipment manufacturers as well as network operators responded to competition in a liberalized market by introducing several new management procedures in order to access future technology developments, to streamline the innovation process, to acquire knowledge from outside the company as well as to make internal knowledge available within the company, and to standardize coordination with customers and suppliers. Other management procedures, such as risk management became obligatory as a result of a going public at the stock market.

4.1 Knowledge Management

Actors in the German telecommunications sector have established various knowledge management procedures at different levels of the company, since a standardized knowledge management system does not exist yet. These procedures are based either on the use of information technology or on the introduction of face-to-face community building measures. The reason for these two different approaches is the existence of two different kinds of knowledge within an organization. Whereas explicit knowledge used to be well-documented it can be distributed via information technology systems such as corporate intranets or groupware systems. Tacit knowledge, however, largely exist as subjective, cognitive, or experimental knowledge which can be shared either by face-to-face communications or through the means of information technology if a company’s knowledge management system manages to transfer tacit into explicit knowledge (Gupta et al. 2000: 17).

The *T-Nova GmbH*, a subsidiary of the *Deutsche Telekom*, conducts knowledge management projects for the DTAG as part of its worldwide technology scanning procedures. It observes developments in the parent company's strategic markets which are summarized in the acronym TIMES (**T**elecommunications, **I**nformation Technology, **M**ultimedia, **E**ntertainment, **S**ecurity). The major sources of this technology scanning are scientific literature, university departments, and external, mostly web-based information services. The processing of the information takes place by preparing so-called *T-Scan Reports* (Technology Scan) which are then distributed worldwide over the corporate intranet.

However, there is a certain skepticism at *T-Nova* that knowledge management procedures will lead to an expansion of the company's knowledge base. That is why T-Nova has also established a competence management system which in a first step explores all existing competences within the company. In case that an existing competence matches the parent company's strategic fields of competence it will be associated with concrete projects or position. A similar system has been established at *Ericsson* to guarantee that the company obtains both strategic (long-term) competences as well as critical (short-term) competences. *Ericsson*'s competence management system consists of three core concepts: the exploration of competence requirements, the analysis of present competences, and the definition of competence gaps. As a result, measures are introduced aimed to bridge the competence gap and they apply to the company and to the individual level (Hellström et al. 2000: 107).

The success of the use of information technology for the distribution of tacit knowledge within a company largely depends on the willingness of its employees to share personal information and experiences and therefore on the company's corporate culture. *Cisco*, for example, early and comprehensively invested in its corporate intranet with the result that today virtually every business process is mirrored within the intranet. Employees from most business fields joined so-called virtual teams which work on various projects independently of time and location. As a result, using the corporate intranet has become an important aspect of the daily workflow of individual employees. For example, a marketing manager at *Cisco Systems GmbH* in Germany estimates that 15 to 20 percent of his weekly working time is related with the use of the corporate intranet, about five percent for the preparation of reports or messages, 10 to 15 percent for information retrieval.

4.2 Product Management

Product management procedures aim at an optimized planning of future products. These procedures combine an analysis of existing businesses, technologies and requirements of customers with an evaluation of businesses, technologies and applications which could be available in the future. In

1993/94, *Siemens* established such a "future-oriented, market-centered joint technology planning" as a new element of its R&D process. These procedures are the principal task of the corporate technology department, however technology planning is certainly done in close coordinated communication with the companies' business groups (Siemens 2000: 5). Starting from today's business, it combines a strategic visioning of long-term future needs with an assessment of near- and medium-term solutions for tomorrow's market. This assessment includes an extrapolation from core technology roadmaps (existing businesses, existing technologies, known customer requirements) and a retropolation from long-term scenarios (new markets, new customer requirements, new applications and technologies) which have been developed as the result of the strategic visioning process. This model also considers external factors of influence such as society, politics, economy, environment, technology, customers and competition. It also applies to all of the *Siemens'* business units which are health, information & communications, energy, industry, and transportation.

Confronted with a growing number of network operators who have very different needs but also limited financial resources, *Alcatel* established a product management division aimed at streamlining and optimizing the development of its products. *Alcatel*'s product management system, which is in basic terms comparable to *Siemens*' system, is based on a time span of five years, thus involving pre-competitive research, development, and marketing. Product management starts with a market review which tries to identify future conditions in terms of end-users, regulation, the overall development in view of technology, services and network concepts, the needs of network operators, and the availability of internal and external knowledge and skills. According to these variables, the product management leads to a definition of targets which have to be implemented by concrete R&D projects. These projects have a duration of less than five years and do normally not extend beyond three years. All in all, the product management procedures result in a concrete roadmap for every product which could become a market success in the future. *Alcatel*'s research center is neither involved in the definition of the targets, nor does it initiate projects. A product management division was first established in 1990 at *Alcatel SEL* in Stuttgart with a total of 15 employees. After the creation of a product management division for the entire company, the number of personnel tripled to 45 persons. Today, *Alcatel* is engaged in product management both at the central level as well as at the decentralized level of business units with about 170 employees, most of them working at the level of business units. Under the project management system, each R&D project is clearly delimited from other projects. They are coordinated centrally, but implemented locally at the various R&D departments of the company.

4.3 Innovation Management

Several actors in the German telecommunication sector have established an innovation management system which is, in contrast to product management, a more comprehensive approach since it has to enable the company to successfully implement new products at the business unit level and to profitably introduce them on the market. On this premise, key factors for an innovation management are customer-orientation, a strategic technology and patent basis, the identification of core competences, and the support of innovative projects by the company's management. *Siemens*, for example has introduced a "top-innovation-initiative" that consists of eight interconnected modules (Weyrich 1998: 68):

- *mobilization and communication*: communicates the importance of innovations and best practices models to employees,
- *idea-initiatives/prizes*: makes better use of employees' ideas and grant awards especially for the implementation of ideas,
- *communication of operational abilities*: communicates utilities and basic technologies for innovation management,
- *patents*: introduces systematic patent reviews and give awards for major inventions,
- *white space projects*: identifies new business and technology fields for the company especially by combining various competences,
- *software initiative*: enhances the quality of software through sharing of information among users,
- *strategic innovation projects*: opens the path for major innovations through systematic foresight of the future development of the industry,
- *cooperation with non-industrial research*: makes better use of the national and international external knowledge base.

The *Deutsche Telekom AG* established an innovation management department in 1999 which is responsible for three processes: a worldwide scanning and scouting of new technological developments, the distribution of knowledge within the company, and the implementation of a company-wide planning structure for research and development. The scanning process is conducted mainly by the *DTAG's* R&D unit *T-Nova GmbH* which has introduced a "technology early recognition process" conducted at several *T-Nova* units especially in Germany and the United States. Because of the activities at different locations, the exact number of employees who are concerned with the process can not be identified. However, within a yearly project planning, the early recognition process is calculated on the basis of five to seven man-years. Within this process, scientific literature, university research and external information services (as it is the case as part of the knowledge management) have to be observed in order to prepare technology descriptions and trend letters. These documents are prepared exclusively for the strategic management division of the *DTAG*. Additionally, since the going public of the *DTAG* in 1996, the company has conducted a regular risk management which includes an analysis of the relevant markets, competitors, and technologies.

4.4 Quality Management

Many actors in the German telecommunications sector - network operators, equipment manufacturers, and research organizations - have implemented quality management procedures based on internationally recognized standards such as *ISO 9000* or *CMM.* Whereas research organizations decided to implement these procedures in order to adjust to well established industry standards, equipment manufacturers have to be *ISO 9000*-certified if they intend to take part in a tender of a network operator. According to an expert of the telecommunications sector, the question of whether an equipment manufacturer is *ISO 9000*-certified has to be answered positively as a precondition for further participation. To be more precise, *ISO 9000* is a family of voluntary international quality standards (of which ISO 9001, ISO 9002, and ISO 9003 are most often used) developed by the *International Organization for Standardization* (ISO) in Geneva as a set of guidelines for the establishment of a quality management system for companies of all sizes both in the manufacturing and service sectors (cf. ISO 1998: 2 ff.). The *ISO 9000*-certification requires a successful implementation of an internal process in which the company defines its targets as well as the expectations of its customers, suppliers, shareholders etc. and then changes its internal workflow in accordance with these definitions. At the end of the process, the company must undergo an independent audit to become certified. Since the main function of the *ISO 9000* management system is to ensure a certain standard of quality of the firm’s internal processes, many companies decided to go a step further and implement quality management systems that allow for an optimization of the internal processes such as the *Capability Maturity Model* (CMM).

CMM has been developed by the *Software Engineering Institute* of *Carnegie Mellon University* in Pittsburgh as a management system aimed at minimizing risks and optimizing productivity and quality in software development. This system is based on five stages, each of them representing a more sophisticated standard of quality: from the "initial phase", in which software is developed with the knowledge of few employees up to the fifth phase, the "optimizing phase", in which the company is in continuous process of capability improvement which allows the firm to manage changes in processes and technology.

5. *Conclusions*

As a result of market liberalization and rapid technological change, the German telecommunications sector has changed significantly since the late 1980s. This holds true especially for the telecommunications equipment manufacturers, which became confronted with growing international competition, increasing price pressure, and shorter product life cycles. In reaction to this new market conditions, the equipment manufacturers established new kinds of relations to customers, competitors and suppliers as they have conducted internal reforms aimed at both gaining flexibility within a large organization as well as optimizing the innovation process by implementing new management procedures. In certain areas, internal reforms were a precondition for new kinds of relations. Only after companies, such as *Siemens*, exposed their own R&D laboratories to competition by reducing institutional funds, universities and non-university research organizations were able to enter the competition for R&D contracts. As a supplier of knowledge for the manufacturers, these organizations had to conduct reforms as well. They implemented quality management procedures in order to make cooperation more easier and more reliable as they began to better market their knowledge through licensing and patenting their research results.

The institutional environment in which the sector is embedded did not only change through the implementation of a new regulatory regime. The reform of the financial system made equity capital available in Germany and thus supported the establishment of small and medium-sized companies in the communications technology sector. Public policies also increased research and development funds at the regional, national, and the European level as they considered modern communications technologies as strategically important for Europe's competitiveness. Further reforms are certainly necessary in the education system. Even though many equipment manufacturers conduct R&D in Germany because of its highly-qualified workforce, the education system does not produce the quantity and quality of human resources as needed by the industry. Not only that a lack of qualified personnel already exists, the training still takes too long as it is considered to be too comprehensive and specialized.

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ANNEX I. T2. TELECOM AUSTRIA

Telecommunications and the Austrian paradox

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Introduction

The European paradox (see Grande 2000) states that though Europe invests heavily in Research and Development, it performs modest in commercially successful innovations. Austria seems to exhibit a somewhat opposite paradox: low R&D investments but, nevertheless, economic success. At a national level the Austrian data suggest that Austria has a relative good economic performance but few innovation. In international comparisons, Austria ranks much higher on indicators such as value added and labour productivity than in traditional innovation measures, like R&D investments and patents. It is often assumed that these are also indicators of low innovation performance understood as commercially successful new products. Is growth without commercially successful innovations a feasible long-term strategy for some countries? And is growth without innovation possible in high tech sectors such as telecommunications?

This paper analyzes the transition from the electro-mechanical to the optical-digital paradigm in the Austrian telecommunications industry from the 1970s to 2000. It is based on a sector study which used open expert interviews for information (see Giesecke/Rossak/Unger 2000). As this paper will show, Austrian telecom actors did not contribute to much technological innovation in this transition period, though they had been one of the first to start with digitalization. Rather, they managed to introduce and adjust foreign technologies in order to construct a modern public network. Why the Austrian innovation system was not able to go beyond the adaptation of foreign imports, except for some few niches, will be explained by analyzing the institutional set up that determines the mode, pace and quality of innovative activities along the idea-innovation chain.

It will be argued that

1. The paradigm shift was an incentive to modernize the equipment industry, but mainly by adapting innovations made elsewhere. The Austrian industry did not become a major innovator itself.
2. The Austrian paradox cannot only be found at a national level but also in high tech telecommunications. Austria's telecommunications does show the Austrian paradox when compared with the Netherlands, Finland and Germany. Its economic performance is better than its

innovative performance would suggest.

3. Growth without innovativeness may be a feasible long-term strategy, but not in high tech sectors. Austria lost its good economic performance position during the transition period. Today it takes the last place in innovation but still does better in economic performance, although its rank order position in the four-country comparison is worsening. The Austrian paradox became less of a paradox than before.

4. Even in a global sector there can be a national curiosity such as the Austrian paradox. National institutions can still explain performance differences. However, the Austrian paradox is a national peculiarity that might become less conspicuous.

1. The Shift from the Electro-Mechanical to the Optical Digital Paradigm as an Incentive to Modernize

The following section will outline the situation under the old and new technological paradigm. It will argue that Austria used the shift as an incentive to modernize the outdated technology but did not become a great innovator. A major explanation for this is the Austrian national institutional setting.

1.1. The Organization of the Telecom Sector under the Old Electro-mechanical Paradigm

The electro-mechanical paradigm was dominant in Austria until the 1980s. At that time, much of the network was already more than 30 years old, demand for communication increased and the Austrian telephone company (Österreichische Post- und Telegraphenverwaltung/ÖPTV) could not quite respond to the growing demand. From 1974 to 1979 the number of access lines had increased from 1,390,456 to 2,033,351 and estimates expected a demand up to another 2 million until the year 2000 (ÖPTV annual reports, several years).[1] The majority of Austrian households, though not the corporations, had to wait several months to get a new access and most of them had to share that access with three other customers (party line). Capacities of the domestic actors,

[1] The penetration rate was 12.2 in 1970 and rose to 43 in 1991 (PTV several years).

ÖPTV as well as equipment suppliers, to introduce a radically new technology in order to modernize the outdated network and establish sufficient lines for all Austrians were practically non existing. In other countries, especially in North America, the digital system had been introduced and revolutionized private as well as corporate communication. This new technology, however, was far beyond what Austrian telecom actors could achieve with their own resources. There were only twelve companies worldwide that could provide the new system, today even less (Interview 23).

At that time, telecommunications was not considered an important economic sector but rather a means to communicate messages, to which every Austrian, in one way or the other, should have access at reasonable costs. In addition, telecommunications was regarded as a sector that provided jobs. The Austrian telephone company was one of the country's three major employers in the economy.[2] By the end of the 1970s, ÖPTV employed more than 60,000 people, 19,000 of which worked in the telecom sector (the others in the bus and postal service).

Access to the telecom network and high employment, were the two political priorities under which the pattern of innovation before and after digitalization has to be seen. The ÖPTV was a state owned monopolist for telecommunication infrastructure and services (supply side) and a monopsonist for terminal equipment (demand side). In addition, until 1993 ÖPTV was the official regulatory body (Ratspräsidentschaft 1999). There were only four equipment suppliers, which were organized in a cartel-like setup. As a consequence, there was little competition for the public network. There was, however, some competition for corporate (private) networks for individual companies, which were not regulated by the ÖPTV (Interview 17).

ÖPTV was organized in the (SPÖ) ministry of economy and transport. Trade unions and social democratic ministers decided upon the future of the telecom sector (Interview 10). The specific configuration played an important role for the future to come. Priorities were to protect the domestic economy, to secure jobs and to control prices and wages. Employees of the ÖPTV were organized in an own powerful trade union, the *Gewerkschaft der Post und Fernmeldebediensteten*. The strong influence of this trade union can be explained by the extraordinarily high degree of unionization (more than 95%) and its good relationship to the ÖPTV management (Latzer 1989: 214; Latzer et al. 1994: 121; Interview 10).

On the other side of the telecom equipment market we find four dominant suppliers. Two

[2] **The other two were VOEST, the state-owned steel company, and the railway company ÖBB.**

of them were foreign subsidiaries, Siemens Austria and ITT Austria, later Alcatel Austria, the other two were Austrian family businesses, Kapsch and Schrack. The four cooperated in a cartel like setting. Their first letters were used as an abbreviation for the cartel, first "KISS" later

Siemens was more than only a foreign subsidiary. It was also considered a state owned company due to its specific history. The young Austrian republic after World War II nationalized a great part of industry in order to safeguard it from Russian confiscation as German property. More than one third of manufacturing workers were employed in nationalized industries (see Hemerijck/Unger/Visser 2000). In 1946, Siemens and its associated companies[3], were also among these nationalized firms. Only in the 1960s, Siemens Germany was able to buy back bits and pieces. In 1971, Siemens Austria AG was founded (which is the company as we know it know). The state held 43.6% and Siemens Germany 56.4 % of its shares. Only in 1990 (!), the state's shares were reduced to 26%.

The telecommunications sector was governed by labor interests. First, the state was a major employer with Social Democrats in power for more than thirty years. They either had the absolute majority or they provided the minister of nationalized industries in the grand coalition. The ÖPTV was organized in the Social Democrat dominated ministry of economy and transport. The same political actors influenced both, the supply and the demand of the sector.

This close connection between the telecom actors cannot be found in any of the other countries. Public tenders, for example could not be allocated to foreign companies if the domestic firms were able to do the job. Further, the contracts were issued according to fixed quotas, so that the companies were able to plan several years ahead. If one of them would encounter some economic problems, for example the break down of export markets, the quotas were adjusted accordingly, so that jobs were not endangered (see Giesecke et al 1999). This close cooperation between the actors of the sector cannot be found in any other of the countries studied.

Until the mid-1980s, the highest priorities of the ÖPTV and equipment suppliers were to offer a functioning communication network and to secure jobs by keeping the value added chain in Austria. Technology policy was not yet seen in conjunction with telecommunications. It did not

[3] **Siemenss' activities were spread among several companies. The most important were Siemens GmbH, Nachrichtentechnische Werke AG and Siemens-Reiniger Werke GmbH. Only in 1971 when the Siemens AG Österreich was established, all companies were integrated in the newly founded one (Hack 1998: 229).**

occur to political actors that innovation in this sector might be important for economic progress. The supplier cartel and their business representatives did not want any new competitor on the market who would threaten their established position. From this perspective, a strong incentive for major innovations could not be expected (Latzer 1989).

Raise of telephone rates had to be approved by the parliament. Price increases for telecom equipment for private and corporate use could not be determined autonomously by ÖPTV (or by the suppliers) but had to be negotiated between the social partners in the Sub-Commission for Prices, where 80% of Austrian consumer prices were regulated at this time.

Therefore, even if prices for phone calls might not have been much higher than the West European average at that time (according to some Austrian experts interviewed), the long waiting periods and the limited quality, however were below average standard that was possible with the existing technologies.

In contrast to the US or Germany, the domestic market was far too small to generate the economies of scale required in order to invest in R&D for an “Austrian switch“. The two Austrian companies of the cartel, Kapsch and Schrack, were mainly domestically oriented. Unlike the Finnish telecom companies, the Austrians were not competitive internationally but were sheltered by the Austrian industrial policy. The two foreign subsidiaries of that time did not undertake R&D for the Austrian market. They were integrated into the parent companies’ R&D fields[4]. They, therefore, mostly imported new technologies from the parent company, which were then adapted to Austrian needs (Interviews 9, 17).

Unlike Finland, where the national telephone companies were liberalized and privatized quite early, the Austrian ÖPTV was not only state owned but also used as a “cash cow“ to stabilize the Austrian public budget. The ÖPTV had three divisions: telecommunication, post and bus. Telecommunication was the only profitable one and had to cross subsidize the other two. In addition, profits could be reallocated to other posts of the national budget. Only between 30% to 40% of the ÖPTVs' profits could be reinvested into the telecom sector. There was a lack of finance, hence.

In addition, the ÖPTV’s own technical department for telecommunications research

[4] **At Siemens for example the software development center PSE (Program and Systems development center = Program- und System Entwicklung) located in Vienna, dedicated 95% of time for developments for the parent company. In the late 1970s and early 1980s PSE developed major software components for switching nodes for the parent company's digital switching system EWSD (Annual report 1980: 27).**

(FZA/Fernmeldetechnisches Zentralamt) reduced its R&D activities in 1955. Until 1955 the FZA was very active in applied research and experimental development. The analogue systems were to a large extent developed by the FZA and then produced by equipment companies. However, since 1955, FZA restricted its activities to testing and monitoring technical developments of the equipment companies. Officially this was explained with budget reasons. Explanations oft the striking fact that the post gave up its own research capacity voluntarily, given in interviews, were that the state had just filled in the role of the equipment companies transitorily. The equipment companies had lost their productions sites during World War II (ÖPTV 1972: 14; Interview 32), so ÖPTV had to develop an own telephone system. With increasing offers from the equipment educed its R&D activites ("Why inventing the wheel twice?" Interview 32).

This lack of an in-house R&D is another striking difference to telephone network providers in the US, Finland, Germany or the Netherlands.

To sum up, both the equipment suppliers and the service and infrastructure providers did not have the financial resources or the know-how to invest in a technology as complicated as the digital switch.

Besides corporate resources, there were of course universities in Austria, which had chairs for telecommunication technologies. They were, however, scarce and oriented towards basic, not applied research. Their research was publicly subsidized and the degree of cooperation among each other or with industry or the ÖPTV was very low (Interviews 9, 23).

It can be summarized that the Austrian economy as a whole, and the telecom sector in particular, were sheltered from any internal or external economic shocks. This protectionist policy which was the outcome of the negotiations between government and labor associations (mainly the *Postgewerkschaft*), resisted successfully the global economic crisis of the 1970s but unfortunately also most of the technological changes and challenges that went on at that time. Nonetheless, by the end of the 1970s, the ÖPTV and the trade unions realized that the old system had to be modernized - not only for technical reasons but also to keep the telecommunication jobs in Austria. In order to prevent foreign competition, the ÖPTV, the cartel and all four (!) social partners took a concerted effort in founding the ÖFEG (Österreichische Fernmeldetechnische Entwicklungs- und Förderungsgesellschaft m.b.H, see below). This corresponds to the good old Austrian manner of compromise and consensus stressed in the neo-corporatist literature (see

Schmitter 1979).

1.2. Introducing the New Paradigm

Digitalization certainly was a turning point in the Austrian telecommunications sector. In the decision to digitalize its switching system, the ÖPTV was one of the first (!) in Europe. This was at a time, when no digital system was yet in operation in Europe. It took seven years, however, until the first switches went into operation, in 1985.

The decision to modernize the network was made in 1977 by the ÖPTV, because the outdated conventional system that had been in operation for more than 30 years, could not handle the rising amount of communication exchange anymore (Interview 9). The first initiative was taken by the works council's[5] of the equipment companies, who approached the ÖPTV. The work council's feared that rationalization and the unsatisfactory order situation could endanger jobs. Consequently the social partners, ÖPTV and the equipment suppliers made concerted efforts to found the ÖFEG (Österreichische Fernmeldetechnische Entwicklungs- und Förderungsgesellschaft m.b.H/ Austrian telecommunications development and promotion company). Their joint interest was to modernize the telecom network by preventing foreign competition and safeguarding jobs to domestic workers. (Bauer and Latzer 1987: VI.120). A new company was formed that would organize the digitalization process. The ÖFEG was founded in 1978 and was a joint venture between the state (represented by selected ÖPTV staff members and the social partners: the Chamber of Labor, the Economic Chamber, the Federation of Trade Unions and the Association of Entrepreneurs) having 50.4% of the shares, and Kapsch, Schrack, ITT, and Siemens each holding 12.4% (Postrundschau 1979/ 2: 8). Any other foreign corporations could not enter the new venture to integrate their know-how because they did not produce any telecom equipment in Austria. One of the ÖFEG's major tasks was to organize the acquisition of competencies required for digitalization that was lacking in Austria (ÖFEG 1998, Interviews 1, 14, 23).

[5] **Back then the chairmen of the works councils of the major firms in Austria were very powerful men. In Austria, they were called "Betriebskaiser" (works emperor). Within a highly concentrated/ organized work force they were extremely influential (Husz 1997: 15).**

For the four established companies this meant further protection and a "fail-safe" business. That was particularly important for Schrack - the smallest firm, but also for Kapsch. Both companies practically had no know-how in digital systems, but had to rely on outside competence in order to develop and adapt a digital system to Austrian standards. Thus, for the two genuine Austrian family businesses digitalization meant an extraordinary chance to enter a market dominated by ITT and Siemens and to expand their operations to a new technological field (Rechnungshof 1975: 132; Interview 9).

1.3. Selection of two systems instead of one, in good old compromise tradition

The role of the four companies within the joint venture was to make suggestions which one of the existing foreign digital systems were suitable to Austrian needs. Kapsch and Schrack opted for DMS 100 of the Canadian company Northern Telecom. The system of Northern Telecom had already been in use in North America with about one million access lines. It was considered a reliable "blue collar system", meaning that semi-skilled technicians were sufficient for maintenance (Interview 9).

Philips' PRX system was rejected because it was judged less technologically advanced. Philips, who had promised to establish a software house in Austria if it would be considered. withdrew completely from the Austrian public telecommunications market in 1981. Before, Philips had occasionally supplied ÖPTV with telecom equipment imported from abroad.

Kapsch and Schrack's choice for Northern Telecom was supported by the Chamber of Labor and by the Austrian Federation of Trade Unions.

The parent companies of the two big equipment firms did not take Kapsch's and Schrack's proposal very serious. They thought that the Austrian firms would not have the know-how to adapt the complicated technology (Husz 1997: 19). Siemens and ITT suggested the systems of their mother companies (EWSD and ITT's System 12-30). ITT's proposal was revised but raised a lot of criticism (Interview 9). Siemens system needed highly skilled personnel, which was a definite disadvantage for a country not familiar with digital telecommunication technologies. The fact that there had been no extensive testing, also raised some doubts about its reliability.

ÖFEG withdrew for three weeks of intense discussions and ended up with a majority vote for the Northern Telecom system DMS 100. Following its recommendations, the ÖPTV decided to take the license from Northern Telecom (Canada). Northern Telecom licensed this technology and created an alliance with Kapsch that lasts until this date (Interview 14).

This decision upset Siemens, who was considered a quasi state owned company and was highly favorized by Chancellor Kreisky. Siemens Austria was the largest Telecom Company in Austria, in terms of turnover and employees. The Siemens executives threatened to stop all joint ventures in Austria if they were not taken into consideration. As a consequence, the chancellor who wanted to keep Siemens in Austra intervened. The social partners accepted the chancellor's decision without any noticeable resistance. It was also in their interest of job protection, of course, that Siemens kept its operations in Austria (Interview 10). Siemens agreed to expand the factory for semiconductors in Villach, Carinthia, and to establish a development center for microelectronics (EZM/Entwicklungszentrum für Mikroelektronik).[6] So, in 1981, the minister of economics and transport finally decided to procure two systems: DMS 100 from Northern Telecom and EWSD from Siemens (Germany). It was never officially assessed, if the federal money invested in the two digital systems in the end paid off (Goldmann 1986: 79, Interview 10).

For the implementation of the two systems that were regionally separated, two licenses were needed. They had to be compatible in order to establish the Austrian digital system OES (Österreichisches Einheitssystem). Both systems were licensed abroad and only partially produced in Austria. For the adjustment to Austrian telecom standards two development organizations were created in the form of joint ventures: AOSA, a formalized cooperation between Siemens Austria and ITT Austria, and Austria Telecommunications (AT) of Kapsch and Schrack (Husz 1997: 20, Interviews 14, 23).

Generally, there was a commitment to strengthen the Austrian telecom industry but no ambition or real effort to gain technological superiority. Austria succeeded in building up some essential technological know-how about digital systems but did not advance to setting technological standards. Domestic developments, instead, were based on foreign licenses
The continuous extension of the Austrian public network with digital technology started in 1985

[6] **The Microelectronics Development Center (EZM) in Villach, established in 1979, serves as a "think tank" (the largest of its kind in Central Europe) to facilitate conversion of less profitable mass produced products (such as memory chips) to highly advanced products (such as chips for highly advanced electronic applications). The Center focusses on measurement and control technology, automotive electronics, communications and microcomputers (U.S. Department of Commerce 2000).**

when the first switches were delivered (ÖPTV several years, Interview 23). By 1992, some 1.5 million of an entire 3.5 million main lines were connected to digital switches, about 42%. In that year, New Zealand had the highest penetration of digital lines (95%), followed by the Netherlands (86%), Finland ranked 14th, Germany 23rd and Austria 24th (OECD 1995: 44).
Altogether, Austria took longer than Finland, the Netherlands and Germany to digitalize its network.

The outcome of the decision for two systems was a fairly expensive network (about ATS 6 billion), with doubled development efforts costs and the long-time burden of higher maintenance and compatibility costs, which also were never officially assessed (ÖPTV annual reports, several years, Husz 1997: 21). The advantage were higher quality and some pressure on the duopoly to supply at world market prices (Interview 23).Parallel to the improvement of voice telephony, the transmission of data was also advanced. In 1995, as a preparation for the upcoming liberalization, the Datakom, a subsidiary of the PTA, was founded to offer corporate networks and value added data services for the free market.

For mobile phones, Motorola and its Austrian partner "Center Nachrichtentechnische Anlagen GmbH were the major suppliers. Just as data services were outsourced to a newly founded firm, so were mobile services. The Mobilkom was founded in 1996 as a subsidiary of PTA. In 1997, Mobilkom had 939,000 customers (PTA 1997).
As Table 1 shows it took till 1999 that the digitalization of the Austrian switching system was finished.

Table 1: Timetable - Technological changes

1969	Introduction of the transmission technology PCM (Pulse Code Modulation) for telephone lines.
1972	The full automatization of the Austrian telephone network was completed.
1974 1977	Start of the first Austrian mobile network (B-network for cars only). Decision to modernize/ to *fully* digitalize the Austrian telephone network was taken. In its decision the ÖPTV was one of the first telecom provider in Europe.
1978	The joint venture ÖFEG was founded between the state having 50.4% of the shares, and Kapsch, ITT, Siemens and Schrack each holding 12.4%.
1981	Decision to procure two systems was taken: DMS 100 system from Northern Telecom (licensed by Kapsch and Schrack)

	EWSD system from Siemens Germany (licensed by Siemens and ITT)
1981	Joint Ventures: AT (Kapsch and Schrack) and AOSA (Siemens and ITT) are founded.
1983	First trial facilities for the digital fixed network.
1984	The C-network was introduced. Based on a radio cell system which implied a fundamental technological advance in mobile communications.
1985	The first digital switches for the OES system went into operation.
1989	First efforts to implement a pan--European digital mobile network (GSM) were undertaken.
1989	Introduction of the data network Datex-L, DDL and the data packaging network Datex-P.
1990	Introduction of the D-network = an interim analogue mobile communications system. It was introduced to bridge the time between the C-Network (which was unable to expand) and the introduction of the GSM network.
1991	Pilot testing for GSM 900 started.
1991 1994	The signaling system No.7 (Zeichenvergabeverfahren Nr. 7) was implemented in all OES switches. This was a prerequisite for the introduction of ISDN plus Intelligent Networks IN and GSM. Commercial start of the GSM 900.
1995	Pilot testing for GSM 1800 which operates on a frequency band of 1800 MHz.
1998	Commercial start of GSM 1800.
1999	Digitalization of the Austrian switching system was finished.

2. Does The Austrian paradox hold for telecommunications?

2.1. The Austrian paradox at the national level

From performance indicators one can see that at the national level Austria ranks lowest in R&D and in patents. but relatively good in economic performance variables such as labour productivity and turnover (see performance chapter).

When looking closer to Austria one can see that the paradox is partly due to statistical problems of traditional indicators. R&D efforts in Austria have been underestimated (Polt et al Austrian Report on Technology, 1999, p.8). Austria's R&D expenditures are low in business, but very high in universities (1993: business 56% (EU: 63%) and universities 35%).

Austria's sector structure also explains the bad R&D performance. R&D intense sectors are missing (office machines/computers, precision engineering/optics and airplane manufacturing). The lack of a military industry is certainly also not favorable for R&D. In 1995, Austria's R&D expenditures in % of value added were highest in electronics and telecom (25.9%) and in pharmaceuticals (22.5%). But these sectors amount only to 6.1% and 2% of gross value added of tangibles production. The big value added producing sectors are food, mechanical engineering, metal working and paper printing, which account for about 40% of total value added, but have only a very low R&D intensity (mechanical engineering 3.9% of value added, the others 0.2%-1.3%). There is a technology pitfall in the Austrian economy. "Limited research input does not pose an innovation problem for the economy, rather is much more an unavoidable result of lacking technology intensity within the manufacturing structure" (Polt et al 1999, p.37). When compared with the three other countries, technology supported value added in tangible manufacturing was 10.7% of total value added in Austria, compared to 13.88% in the Netherlands, 26.13% in Germany and 27.69% in Finland (p.36, data from Peneder).

Sector specialization and international technology diffusion (Austria imports technology) explain parts of the puzzle. But how about the paradox in one specific sector?

2.2. The Austrian paradox in telecommunications

Polt et al (1999) show that Austrian electronics and telecommunications lies above OECD average both in gross product and in R&D quotas. According to their findings, Austria has a structural and R&D advantage in this sector compared to the OECD-14 average. Austria lies 8 percent points above the OECD R&D quota (according to Austrian statistic, European Community Innovation Survey data show a much lower R&D intensity). High gross product and high R&D imply that the Austrian paradox cannot be found in telecommunications in the fourteen countries compared. But when ranking only the four countries Austria, Germany, Finland and the Netherlands, the paradox can be found in these EU-4 countries (see performance chapter). Austria ranks last in R&D and patents.

This might, as in the national paradox case, partly be due to measurement problems. R&D in telecommunications are, however, more likely over- than underestimated in telecommunications. As we found in the Siemens case, 95% of the Austrian subsidiary's' research time was devoted for the mother company in Germany. R&D expenditures and personnel in Austria do hence research for Germany. The Austrian paradox would be even bigger when corrected for this fact.

But patents can be underestimated. As our telecommunication study on Austria shows, Siemens Austria has to patent in Germany for the mother. Patenting in a small country is often not very attractive for MNEs. If know how is attributed to the mother company, the patent statistics underestimate Austrian invention capacity. Also the Technical University TU who patents first in Austria and then sells its patents for international patent application to global players such as Nokia International will not show in the Austrian patent performance in international statistics (see later). Furthermore, sales and turnover can be problematic. Some companies use Austria as a location to the East. Turnover is in the balance sheets of Austria, but the parts have never seen Austria but went directly to Hungary or Poland. This might show in high turnovers but low value added

The survey data show Austrian entrepreneurs to be more innovative than "objective" numbers. But the European Community Innovation Survey data refer to electronics as a whole in manufacturing and to telecommunications services only. Here the sector definition is not precise enough. But if the results are representative, the better survey results might be due to successful niches that Austria could create in telecommunications, in particular in voice processing and smart antennas. It might also be that smaller firms that do no R&D or patenting are innovative, for example in services and design. But it might also be partly the result of Austrian culture, that lacks the Dutch modesty effect. Austrians like to circle extremes in a survey.

From the case study and qualitative interviews of our study one gets however also the impression that even if Austrian telecommunications performs quite well by international comparison, it does not stand the comparison with high tech countries, like Germany, Finland or the Netherlands.

3. Growth without Innovativeness – A Successful long -term Strategy In High Tech?

Can a country succeed in terms of economic growth (in sales, turnover, value added) with low innovativeness? The Austrian paradox is a proof that it can. Austria is a perfect example that a country does not have to be innovative in order to have economic success. Austria's results confirm the study of Geroski (1995) who cannot find an empirical correlation between innovation (data from surveys and patents) and corporate profits. This can e.g. mean that nevertheless, others reap the benefit! Polt et al (1999) use CIS data and find no significant influence of innovation variables on employment. "Technologically new products and not the improvement of existing products create significant increases in both turnover and subsequently, employment" (p.88).(The study did not analyze spill overs of innovation to another firm!). Market demand still counts more for employment and growth than innovation.

A country that specializes in non research intensive production and services can be a successful manufacturer and service provider without engaging in technological innovations and heavy R&D expenditures. But can the Austrian paradox persist in a high tech sector? Can the telecommunications sector be and stay prosperous in a country that invests less in research than others?

In the following the changes in actor constellation since market liberalization in telecom, the behavior of the new entrants and the major trends in the Austrian telecommunications sector will be outlined.

3.1. Market Liberalization and the Change in Actor Configuration

In many countries, the new digital technology laid ground for breaking the monopoly of the public telecommunications. In Austria (and as we can see also in Germany!), however, it stabilized the old actor configuration (see figure 1). It was not digitalization, the technological push, but liberalization, the economic push that initiated major shifts in the network infrastructure and services. The liberalization of the Austrian telecommunication market (services) eventually occurred because Austria joined the EU in 1995 and had to concede to the EU laws of telecom liberalization until 1998. In fact, Austria was one of the last countries in the EU to follow this directive. The resistance of the insiders to any attempts of fundamental reorganization lasted until the last minute. Figure 1 shows the actor constellation in the 1980s during the implementation of digital-optical technology, and figure 2 the new constellation in 2000, after the digitalization had ended and liberalization had started.

INSERT FIGURE 1(former 2) and Figure 2 (former 3) d:\tser\Structure of Austrian telecom.ppt

At the top of each figure (end user level) one can see the client structure that remained basically unchanged, consisting of private and of corporate clients. In addition, there have always been some state owned companies such as the railway company (ÖBB) and some energy suppliers which were allowed to build their own corporate telephone network infrastructure across the country but had to rely on the ÖPTV when calling to the outside world. This is a special group of client that one finds in almost every country.

In the middle of both figures one can find the network infrastructure and service providers. In figure 1 this was the ÖPTV's role. Compared to the 1970s, the most significant changes in actor configuration that digitalization had brought about was the creation of *ÖFEG*. And the two development teams AT and AOSA. Kapsch and Schrack had cooperated before, so they formed AT (Austrian Telecommunications) to license and adapt the technology from Northern Telecom. The fact that Siemens and ITT formed a working group named AOSA, however, was less evident from their own understandings. They had always been competitors, within Austria, but to a much larger extent outside of Austria. In addition, the fact that a technology of Siemens was licensed and not the one developed by ITT was – under the surface – interpreted as a failure by ITT[1]. Apart from *ÖFEG*., AT and AOSA, the configuration of the equipment suppliers in fixed line telephony did not change much between 1970 and 1980.

The cartel of the four suppliers remained unchanged, except that in 1987, KISS changed to KASS, when ITT was renamed to Alcatel. For these companies digitalization meant strengthening their position in the fixed-line telephony, further protection and a "fail-safe" business, also because digitalization was not just an "event" of one or two years. That was particularly important for Schrack – the smallest firm, but also for Kapsch. Both companies practically had no know-how in digital systems, but had to rely on outside competence in order to develop and adapt a digital system to Austrian standards. Thus for the two genuine Austrian family businesses of that time digitalization meant an extraordinary chance to enter a market dominated by ITT and Siemens. In mobile telephony, the US company Motorola entered the Austrian mobile telecommunications market after winning several tenders for the setup of mobile networks. Since the beginning of the

[1] **ITT's system 12-30 was however not fully developed and already deficient in capacity.**

digitalization Kapsch and Northern Telecom, now Nortel, have established close cooperation and even formed a development joint venture called Nortel-Kapsch.

Today, the major suppliers of the fixed-line network are still KASS, a term that is not applied anymore: Siemens, Alcatel, Kapsch and now Ericsson which bought up Schrack in 1992[2]. In figure 2, after liberalization of the Austrian telecom market in the 1990s we see more entrants. Among these new entrants are long-time established global telecom corporations such as Cisco, Philips, Lucent, Nokia and others. They are more prominent on the Austrian mobile than on the fixed wired market. The new entrants have just their sales offices in Austria though, but no noteworthy production or R&D facilities.

In figure 2 one can find a number of additional carriers, network operators and mobile phone providers. Carriers, like Tele.ring, CyberTron, UTA, Verbund Telekom, RSLcom, Connect, Telenor and a couple of others offer access to lines and services to corporate and private clients. Carriers are network operators who compete with the former incumbent. They own a network, switches and other components to manage their network and to use it commercially. All of these carriers have to different extent built their own infrastructure but still depend on Telekom Austria's (the follower of OePTV see later) connections to the last mile. They vary in terms of network length. In addition to those mentioned above, the most prominent are Telekabel, MCI and Colt. The Cable Company Telekabel is one of the companies in charge of the Austrian fiber optic network. Fiber optic cables allow a much faster transmission than any other technology available at the moment. Meanwhile, this company is offering all three, cable TV and telephone lines and internet access, and in addition is renting out telephone lines to other alternative providers.

Network providers are companies that offer network infrastructure to corporations, often by renting these capacities from carriers.[3] Such are Concert, Worldcom, Swisscom, Teleforum, All Trade to name just a few. All these companies are required to obtain a concession, which is granted by the new regulatory agency Telekom Control. By the turn of the millennium the number of concession holders amounted to about 100. In 1999 the alternative providers accounted for a turnover of ATS 14.8 billion and employed some 4,500 people. Investments were ATS 11 billion.

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[2] **Ericsson increased their share to 51%.**

[3] **Value-added service providers did not require PTV's authorization of approval to provide services. It was sufficient to inform PTV of the intent to provide such services. If such an operator wished to provide services in an area already covered by the PTV monopoly, however, a formal request of the granting of a concession had to be made (Espicom Business Intelligence 1999).**

The alternatives' share of fixed wired voice telephony was 15% of the Austrian market in 1999 (TA annual report 1999: 15).

In the 1990s also the chain of suppliers has become longer. Today companies concentrate on their core businesses, thus outsource other activities such as production of very specialised parts and in some cases also sales, distribution and maintenance. This increasing division of labour gave other companies a chance to fill in niches that opened up.

In 1996, following a new legislation, Post and Telekom Austrian (PTA) was formally established as a first step to prepare and restructure for partial privatization of the (former) ÖPTV,. Partial privatization was required to be implemented by the end of 1999 (Espicom Business Intelligence 1999).

At the same time, some of the former ÖPTV'S operating divisions were restructured with the intention to make PTA a more customer-oriented and cost-efficient company than the ÖPTV as a government agency ever was. Most noticeable in this respect was the founding of a fully-owned data communications and value-added services subsidiary, the Datakom Austria AG. This company integrated the former ÖPTV's value-added services business and the data communications services that used to be provided by the former Radio Austria (see historical part). Subsequently, Datakom established an international relationship with British Telecom's global services business, Concert Communications Company (PTA 1998).

In addition, PTA has created an independent profit center for its mobile communications business in 1995, named Mobilkom Austria AG. A 25% stake in Mobilkom was sold to STET Mobile Holding, which is a subsidiary of Telecom Italia. PTA's telecommunications-related subsidiaries, including Mobilkom and Datakom, have become direct subsidiaries of Telekom Austrian AG (PTA annual reports, several years).

Preliminary plans for the privatization of PTA were announced in December 1997. As a start, PTA spun-off its telecommunications business from the postal and transport businesses. Up to 25% plus one share of the telecom business which was named Telekom Austria AG was sold to a strategic partner, Telecom Italia, the former Italian incumbent, in the fall of 1998.

In November 1999, Telekom Austria started the commercial use of ADSL, providing 25,000 access lines to all the state capitols. Investments for these modernization efforts amounted to ATS 150 million. As provider of ADSL, Telekom Austria chose Alcatel.

Telekom Control has assessed that the following companies have the dominant[4] market positions:
Mobile communication: Mobilkom and max.mobil
Switches: Telekom Austria and Mobilkom
Fixed networks: Telekom Austria
Rented Lines: Telekom Austria.

To sum up, liberalization marked the end not only of the infrastructure monopoly but also the end of the oligopolist structure of the suppliers (KISS/KASS). From now on the four companies traditionally supplying the Austrian market were competitors. In addition, new foreign firms entered the market and competition increased even more. Thus, since the liberalization, the Austrian telecom market showed some unknown economic and technological dynamism.
The digital fixed network is still supplied by the former KASS due to the complexity of the Austrian network. Foreign competitors have not managed to win a public tender because the know-how of the Austrian fixed network is with those companies that made the adjustments and installed the digital technology (Interview 23).

The story of the mobile sector is quite different. Here we find much more competitors. Though Alcatel, Siemens, Schrack and Kapsch were suppliers of the mobile sector before liberalization, Motorola was able to win some major public tenders. Later, since the mid-1990s, other foreign companies were contracted to deliver certain components to the mobile networks that have been established since. These were companies like the British Coherent Communications System who supplied Echo Cancellors, or Metrica for monitoring growth in traffic levels as new subscribers join the network, and Nokia to supply base stations and base station controllers as well as network management systems.

Since the re-engineering activities that were introduced by this liberalization process, most equipment suppliers have reorganized production activities in order to have a leaner organization that is easier to manage and more profitable. New companies have been created around these production facilities, making the chain of suppliers longer. Production facilities were either outsourced as in the case Dovatron, which used to be a production site of Schrack/Ericsson but was recently bought by a US company. The second possibility is that already existing production

[4] The term dominant applies to companies that have no or no significant competition or control more than 25% of the market. The market share is determined by data on sales.

companies with a traditionally broad focus now start to concentrate on specific components for the telecom sector such as the Styrian AT&S which has some of the world leading telecom companies (such as Nokia) as customer.

3.2. Trends of the Austrian Telecommunications

There are some signs that the future of the Austrian telecommunications lies in narrower niches than before. Firms have reduced their R&D activities, the number of competence centers has been reduced, new entrants mainly use Austria as a sales office for the East. Global players scatter their activities round the globe, but their research activities stay in the head quarters or concentrate in specific countries, such as Germany for R&D (see German chapter) or Finland (see Finnish chapter).

Austria's activities lie mainly at the end of the idea innovation chain. Though Austria has managed to specialize in niches of the development of voice processing and smart antennas. This strategy will not make it a high tech global player and – for the time being – it creates doubts whether the Austrian paradox of high economic success with low innovation can be maintained in the long run.

3.2.1. Reduction and Restructuring of R&D

Along the idea-innovation chain, basic research did practically not exist at companies when the digital system was introduced. Universities did conduct basic research though, but departments for telecommunications were limited in number. In addition, transfer of knowledge was constrained. Cooperative research between university departments and companies did not exist at that time. If both actors cooperated, this was mainly done via contract research[5]. Still, contract research implies that the process of R&D is predictable and the results transferable (i.e. codified or incorporated form), thus from this point of view it cannot be expected that this form of cooperation contributed to a major technological break-through at the companies.

[5] **Contract research means that a clearly defined problem is to be solved by the firm that receives the order.**

Since fully digital technology was licensed from abroad, applied research at companies was cut down too and restructured in small niches (traffic control, railway communication etc.). Development departments to a large extent thus worked on the adjustment of imported technologies to Austrian specifications and the development of software for mother companies (e.g. Siemens and Alcatel).

Basic research at universities

Austrian telecom equipment companies did almost no basic research. Universities were the only institutions conducting basic research in Austria.

Austrian research in telecommunications takes place at three universities: technical university Vienna, technical university Graz and Johannes Kepler University Linz. All in all, there are eight professors holding a chair, plus seven assistant professors. Whereas the technical university Vienna focuses on more fields in telecommunications (digital signal processing, optical telecommunication, mobile communications, codifying and data transmission), university research in Graz is restricted to satellite communications (main partner was the European Space Agency ESA) and in Linz the 'Institute of Communications and Information Engineering' undertakes research in the field of wireless communication and wireless sensing (main sponsors were BMW Munich, Infineon Technologies Munich and Siemens AG Munich

There is no cooperation among the universities, which might have to do with the high degree of specialization. There is also not much cooperation with Austrian companies but more with the parent companies of Austrian subsidiaries. Companies increasingly use universities to do their research – though to a lesser degree than in Germany. At the beginning of the 1990s, 60% of research was financed by the state, 40% by contract research. This changed drastically: now, the state is financing only 10% whereas 90% are financed by commissioned work.

University inventions are patented in Austria, where it is cheap and then sold to global players for international patenting. The TU Vienna, for example, executed three projects financed by the FWF, which all resulted in patents[6]. Nokia Research Center, Helsinki, bought one patent

[6] **The results were first patented by Prof. Bonek (as a diploma engineer there is no requirement for a lawyer) in Austria for financial reasons (it is relatively cheap to patent in Austria compared to an international patent). With the Austrian patent, the TU asked companies if they were willing to buy the patents which was eventually done by Nokia Research Center, Helsinki and the Innovationsagentur. Both then applied for an international patent (Interview 04).**

for "smart antennas for mobile communications". Another one was bought by the Innovationsagentur (Fakultät für Elektrotechnik und Informationstechnik 2000: 14).

Research Centers for Applied Research

Public funded research institutes did conduct applied research in the field of telecommunications, however they were far too small both in total number[7] and size to be involved in the digitalization process. The Centers execute some research for such prominent companies as Philips, Siemens, Motorola, and Telekom Austria. These projects are for the most part contract research.

Reduction of Competence Centers

Since the digital technology became the dominant paradigm and because of the fact that Austrian companies did not have much knowledge about digital systems and the fact that R&D for the eventually licensed digital system was basically done in Canada (Northern Telecom) and Germany (Siemens), the general trend was that R&D capacities in this field were minimized or restructured. If restructured, the firms tried to redefine their product portfolio and the organization of the value chain, confining to the fact that they would not be major players in the switching market for public telephony, neither abroad nor in Austria. This trend was further enhanced when Austria became a member of the European Union in 1995 and the telecom market had to compete internationally without protection of the Austrian government. The companies had to define their roles and niches as participants of the global division of labor.

To give some examples: Alcatel reduced its competence centers in Austria (Alcatel 1994). In the future the French corporation will concentrate on two main segments: telecommunication competence centers for call-center-application and operator assisted services, both located in Vienna, and railway security technology with a second competence center at Vienna (Interview 21). Some development and distribution for the corporation still takes place in Austria but not the production anymore. In 1998, 50% of the 1,160 employees were engineers, 300 of them were employed in the development department. 800 employees work for distribution and services. They are relocated to a subsidiary called Alcatel Austria GesmbH. This spin-off will play a key role for

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[7] **Basically there were only two publically funded research institutes in Austria at that time: Joanneum Research and the Austrian Research Centers Seibersdorf. Only very recently (in 1999) a new research insitute, the "Forschungszentrum Telekommunikation Wien = FTW, exclusively focused on telecommunications research was established.**

the East-European market. The Vienna service center is training professionals who are supposed to take over the distribution and maintenance of Alcatel telecom solutions in Russia and other Eastern countries Interview 21). In 1998, Alcatel Austria AG spent ATS 147 million on R&D, that is 10% of the turnover.[8]

3.2.2. Austria – Sales Department of Global Players

There are some indication that in particular new entrants use Austria as a sales office to the East. This means that not much value added is produced in Austria. Economic success cannot stem persistently from transferring goods from one country to another, from being a transit trader so to speak. The new entrants since liberalization are long-time established global telecom corporations such as Cisco, Philips, Lucent, Nokia, who just have their sales offices in Austria but no noteworthy production facilities or even R&D departments.

The fact that Austria was among the last countries to liberalize its telecommunications market, partly explains, why the new entrants are still rather small and have often only sales offices in Austria. However, this can be catch up effect showing that Austria is a latecomer. According to experts all these companies still expand their business and value added activities in Austria (Interview 33 and 34). The Austrian subsidiary is responsible for the product development, production, marketing and sales of BusinessPhone (extension systems), which is a division of the Ericsson corporation. BusinessPhone private branch exchange systems is completely within the Ericsson Austria field of competence. In 1998 more than 1.2 million extensions were made at the Kindberg plant and delivered. 90% of annual production is exported to around seventy countries throughout the world. The takeover from Austria's family business, Schrack, by global player Ericsson in 1990 also shows the sales orientation. Apart from the specialization on business phones (corporate networks) that stems from the Schrack enterprise, products that are sold here are available worldwide. Research of any kind does not take place in Austria (Interviews 20, 22). The main Ericsson production site for corporate phones has been

[8] **The French corporation Alcatel builds next generation networks, delivering integrated and-to-end voice and a data communications solutions to established and new carriers, as well as enterprises and consumers worldwide. With 120,000 employees and sales of EUR 21.3 billion, Alcatel operates in more than 130 countries (Alcatel 1999).**

disintegrated to a US company, Dovatron International, which still is an Ericsson Supplier in 1999. This is in accordance to the Ericsson strategy to focus on entire telecom solutions and to outsource electronic hardware production to specialized enterprises. The sales unit was outsourced as well but is still a subsidiary of Ericsson Austria AG.

3.2.3. Product Specialization and Successful Niches

All established suppliers in Austria started to concentrate on the core business and to outsource other activities, especially production and in some cases also sales, distribution and maintenance. The increasing division of labor gave other companies a chance to fill in niches that opened up along the value chain. At the upstream end we find producers of semiconductors, PCBs and other components such as AT&S, Dovatron etc.

Product specialization was not directly influenced by the introduction of the digital system, instead it was influenced by two other factors: first the path dependence of what the companies had produced or developed in the past, based on the knowledge, market share and customers they were able to acquire (for example: the concentration of Siemens' unit for software development in Vienna); and second by Austria's accession to the EU, the subsequent liberalization of the markets and the increased competition. Switches used to be the challenge of the past, digitalization was finished. Austrian telecom companies had to develop new strategies (Interviews 13, 14). Successful Austrian niches are voice recognition and voice processing , smart antennas, optical fiber cables and software development.

Generally, one of Austrias' strengths is software development: one is Siemens's PSE division which is among of the biggest software houses in Europe.

Developments (again software based) in the technological field of voice recognition are also seen as a niche of Austrian firms. IBM, Philips and Alcatel are very active in this niche.

In the field of XDSL Austria too has an excellent international reputation. The newly created research center for telecommunications in Vienna (FTW) is very active in this field. The same holds for Siemens, Ericsson and Kapsch. Another niche designed for the new mobile generation UMTS are the major components smart antennas This field is covered by Siemens and the University of Technology Vienna. Research in PRS technology (done by Infineon see next point) is also considered of high international reputation.

3.2.4. Path Dependency of Software Development

The Austrian subsidiary of Siemens still has an impressive portfolio of activities: from energy to traffic, medical technologies, consumer electronics and several others to communication technologies including public and corporate networks. Major focus areas of Siemens Austria's development activities are located in software and system integration, microelectronics, power supply and electronics.

Siemens Germany's R&D activities in Austria were largely concentrated in two centers: the PSE (Programm and System Entwicklung – programme and systems development) and until 1999 also the EMZ (Entwicklungszentrum für Mikroelektronik development center for mircoelectronics). In the course of Siemens Germany's company restructuring "Infineon Technologies" was created in 1999. The EMZ thus now belongs to Infineon Technologies.

The location in Austria became relevant when Siemens Germany had absorbed all software engineers available in Germany, so Siemens[9] started its programme and systems development activities in Vienna already in 1959 (Hack 1998: 691). People in Austria were well trained and even available for lower salaries (Interview 16). Back then PSE employed some 80 specialists; the number of employees in PSE was constantly enlarged to 1300 employees in 1984 to some 3000 in 1997. Due to the availability of skilled labour further development sites were opened in Graz (1979) and Salzburg (1986). PSE was one of the biggest software houses in Europe already in 1984. Siemens *Austria* (!) also established development sites in Bratislawa (Slowakia), Budapest (1995) and Prag.

PSE focuses on support software for various fields: data processing, applications for medicine, automation, communications and audio- and VCR technology. In 1996, PSE employs 2955 persons who are particularily international successful in Telecommunication Management Networks and Intelligent Networks (Siemens Austria 1996: 14).

The high share of development costs and personnel at Siemens Austria is due to the

[9] **PSE officially is a department of Siemens Austria!**

concentration of software engineers in the PSE division. PSEs' developments are largely for the parent company Siemens Germany (95% of all developments) (Interview 16), so developments were not specifically for the Austrian market but always for the global market.

The EZM (Entwicklungszentrum für Mikroelektronik) was established in Villach (Carinthia) in 1979, next to the Bauelementewerk (factory) for integrated circuits. Back then EMZ employed 30 specialists who were trained as microelectronics specialists for 2 years in Germany and the US. The EZM focuses on the development of integrated "standard-curcuits" for the world market and customer – specific circuits for the Austrian industry.

Villach was chosen because of its geographical proximity to Munich, in addition Siemens received several subsidies for its settlement in Villach and skilled labour is available (HTL for electronics in Villach which provides medium-skilled labour and since 1996 Villach also has a Fachhochschule for electronics) (Hack 1998: 474-476).

Along the idea-innovation chain in the telecommunication sector, Siemens Austria AG does not concentrate on basic or applied research. The major focus is on software development at Siemens's PSE division, which had always been a big asset of the Austrian subsidiary. PSE, however, does not exclusively develop for the telecom market but also for other sectors. About one third of the engineers are involved in telecom development (about 1,000, at PSE Munich 3,000 engineers are involved).

Another successful operating division of the Siemens communication division is Information and Communication Products (ICP), comprising computer systems, IT-services and communication devices. For the sales of communication end products, ICP surpassed the ATS one billion line, due to the strong increase of demand of mobile phones. (Siemens Austria annual report 1999).

Often, so also at Siemens (e.g. call centers), the Austrian task is rather to make the specific customized adjustments (today mostly software) for the standardized hardware.

3.2.5. Escape small size handicap

The Austrian family businesses did not manage to conquer the international markets on their own. There was no Nokia success story of finding a niche broad enough to become a global player.

Both Austrian family owned equipment suppliers were taken over by global players.

The Kapsch Group comprises Austria telecommunications (AT) for public networks, Combitech Traffic Systems for traffic control and toll technologies, Electonics & Communications Systems for corporate networks, railway, tunnel and emergency communication, a research center in Switzerland for traffic control systems, Nortel-Kapsch for R&D on public networks, as well as several sales divisions in Austria and Eastern Europe for public and corporate networks and for niche technologies (Kapsch 2000b).

As a system producer, Kapsch is too small to develop key technologies that would be compatible internationally. The firm simply cannot generate the economies of scale required as can a global player like Nokia or Siemens. This is why Kapsch adopts a lot of foreign licenses for the Austrian and the Eastern European market. Major partner is the Canadian telecommunication corporation Northern Telecom. By licensing technologies, e.g. for digitalization, from Northern Telecom, Kapsch makes the necessary adjustments in order to sell the products in Austria and Eastern Europe (not a technological but a regional niche). Accordingly, Kapsch is not active in the first two phases of the idea-innovation chain, but rather import know-how and technologies as far as public and corporate networks are concerned. In 1998, some 500 engineers worked in the development department (plus 559 employees at the production sites). Development for public and corporate networks takes place only in Austria and some in Hungary.

A software niche for Kapsch is Webforgroups, a new software using Java Conferencing and Shared-Application Systems to integrate collaborative work, telelearning and teletraining in the field of parallel-computing. Due to the positive market feedback, Kapsch decided to found a subsidiary for this product, Webforgroups GmbH, representing a new strategy for Kapsch. Customers are leading internet providers, regional providers for internet services and corporations maintaining a supra-regional structure. This software manages, for example, to integrate all employees at various locations of the world to work at one project by combining internet, email, fax and telephone (Kapsch 2000).Kapsch sees GSM-mobile telephony and ISDN as future challenges. Kapsch is the only supplier for Mobilkom, the mobile company of the Telecom Austria (former incumbent

Though Kapsch profits from the new exports markets, it is not a major innovator among international competitors.

3.3. Strategies of knowledge management

3.3.1. Sources and acquisition of knowledge

One of the biggest problems the Austrian telephone company ÖPTV faced when a digital system was to be introduced was the lack of knowledge about the new technology. This knowledge was neither present at the ÖPTV, nor at the equipment suppliers, nor at the universities or any other research organizations. ÖPTV thus created ÖFEG to organize the digitalization process as its strategy to fill in the knowledge gap.

Apart from AOSA, AT and a few other occasional exceptions, the degree of inter-firm cooperation was low in Austria. It was not seen as an instrument of knowledge integration. In this respect, ÖFEG was really the first major attempt to start cooperation across suppliers.ompanies also integrated know-how by hiring sklled personnel either directly from the technical universities, the Fachhochschulen or the HTL's or they hired professionals with some work experience from other companies and sometimes also from the PTT.

Cooperation became more intense only during the 1990s when Austria started more participation in U projects. These common projects rather than resulting in innovations, served to establish informal contacts and to monitor technological developments at other companies or research organizations (Interview 27).

The Austrian telecom actors did surely not use all sources that would have been available theoretically. By taking a closer look at the Austrian situation at the 1980s, however, it becomes clear that many sources of knowledge we have today were underdeveloped back then. One "natural" strategy to integrate new knowledge into ÖFEG would have been to establish links to universities or other research institutions. The problem in Austria however was firstly that there was not enough technological know-how at Austrian universities or research organizations. Secondly, the innovation process was still strictly organized according to the linear model: basic research was done almost exclusively at universities and applied research and development at companies. Knowledge is transferred if both actors are linked. In Austria, cooperation was however almost absent.

The only contacts between industry and academia were the occasional exchanges of students for writing diploma theses or dissertations. Results that derived from research at universities were usually published in scientific journals but there was no additional efforts to disseminate the know-how elsewhere (Interviews 1, 9, 16). For corporations scientific journals are not a major source of knowledge as this is too far apart from development and application (Interview 15).

Knowledge or advice from other resources, such as professional consulting, industry associations or consumer groups were also not considered. The absence of technology policy for telecommunications at this time certainly enhanced the lace of knowledge acquisition.

3.3.2. Management and Retaining of Knowledge

Until liberalization of the telecom market, most engineers would stick to their companies for a lifetime and the older generation working in an Austrian company has spent an average of 20 to 30 years within one company. From this perspective retaining knowledge was not an issue. The new generation, those who are in their late 20s to early 40s, has much more job opportunities as more companies enter the market. Though these companies are mostly service companies, they do have a high demand for engineers. If an engineer cannot move up to the top at one company within two or three years, he/ she is likely to move to another company (Interview 13).

Most companies are aware that the people they employ have a lot of knowledge that is "sleeping". This does not refer to tacit knowledge but to knowledge that could be codified if one knew that it existed. In order to optimize the knowledge exploitation, some companies have begun to establish databases for knowledge where every employee inserts the field of his expertise.

Outside the company, the joint development ventures are common strategies to optimize and retain knowledge. There has been a considerable effect on establishing a domestic knowledge base on digital telephony in Austria through the foundation of the ÖFEG and the cooperation among KASS, especially when we consider that the know-how had been very limited before. Through the foundation of this company, the engineers were able to acquire detailed knowledge of how the system was to be implemented, how it was to be run and maintained. In addition, this was also the knowledge base for further developments such as ISDN, broad band ISDN, GSM and Intelligent Networks.

Contact between science and industry have increased over the last years, in part due to the fact that national policies started to support these kind of cooperation and that international projects increased.

From the trends in the telecommunications sector – reduction and restructuring of R&D by established companies, location of specific tasks mainly sales and training of personnel for the East, concentration on the core business and outsourcing, selling of national patents for international patenting, joint ventures with global players who reduce production in Austria, one can conclude that the Austrian paradox might become less because turnover and value added might grow less in the future. Given the fact that niches become smaller, it is not to be expected that Austria's ranking in innovativeness will increase.

4. A National Paradox in a Global Sector?

Can there still be an Austrian, i.e. national paradox/or innovation system? In a global sector such as telecommunications? Does the nation and in particular the national system of innovation still explain performance differences?

The Austrian paradox raises the question, why do the three countries that have similarities with Austria not display the Austrian or European paradox as well? Why don't we find low innovation in Finland that is also a small open economy? Why don't we find good sales but low innovation in the Netherlands that is also more trade than technology oriented? Why don't we find low innovations in Germany that is also strong in traditional manufacturing? Why in Austria?

Telecommunications has become a global sector. But national differences apparently still persist and global players have found strategies to profit from this. National institutions created a different environment in which firms settled down specific activities and in which they operate. The case of the invention of Corporate GSM at Siemens Austria shows the typical behavior of established global players in Austria. In the past, employees needed three phones: for the public mobile network, for the corporate mobile network and for the fixed wired network in their offices. With Corporate GSM all applications are integrated in one phone; all major PBX features, including forwarding and conferencing are possible; mobile access to time-management tools and voice mail are included as well as access to corporate information (Interview 15, OPUSWAVE

1999).

The "hand-over" of a (mobile) phone call from one telephone base to another is one of the core competencies of the Viennese Siemens. The idea was born by this team. The prototype was finished in three weeks. Opuswave a small company in Colorado, that had just been bought by Siemens and was specialized on IP technology, together with Siemens prepared the upscaling. About one year after the idea was born, the final product was launched by Siemens Munich and Opuswave Colorado (Interview 15).This example illustrates the international division of labor at Siemens, e.g. the strategic location of competence centers, rather than any Austrian "specialty". But it also shows path dependency. The Siemens department just happened to be in Vienna, due to the historical fact that the cheap availability of high quality engineers had motivated Siemens to create R&D in Austria. National institutions either today or in the past play a role for today's events in the sector.

4.1. The Contribution of National Institutions to the Austrian Paradox

National Innovation Systems comprise a set of national institutions that are supposedly relevant for sector innovations. These are, in particular, the modes of financing, public sector support, the educational system and the legal system (see Edquist 1997). In the following it will be shown that Austria's public support for telecommunication is very low. Telecommunication was never a policy priority. Business relies mainly on its own resources and on bank financing. This mode is said to promote more careful types of innovation than stock market financing, where high-risk innovations can find financiers. Austria's education system is fairly good but focuses on the average level of education, hence it lacks both extremes, very skilled and very unskilled labor. This can be a hindrance for high tech innovations, which necessitate a fair amount of high skilled engineers. Austria's legal system, in particular regulatory style, aimed at conservation not fast changes. The Austrian institutions are, hence, not highly stimulating for high risk innovations but rather stimulate incremental innovations and adaptations to the international status quo. They were designed for small and medium sized firms, which account for more than 90% of Austrian enterprise, in traditional sectors and not for global high tech players of considerable size.

Austria's institutions contribute to the Austrian paradox in telecommunications. There is only little public R&D expenditure, technology policy and subsidies do not preferentially promote this sector, the financial system is not adequate for large scale financing and the cooperation of universities and private companies is weak. All this contributes to Austria's low innovativeness.

4.1.1. Low Public R&D Financing for Telecommunications

Public funding amounts to about 5% of corporate R&D, a share that is unusually low among EU countries. Austria's public funding shows a lack of promoting basic research, and modest amounts for applied research. There are two major research funds, which were both established in 1967. First, the FWF (Fonds zur wissenschaftlichen Förderung/Austrian Science Fund) that supports academic work, which is mainly basic research. Second, the FFF (Forschungsförderungsfonds für die gewerbliche Wirtschaft/Industrial Research Promotion Fund), for company research and development. The FFF, which is financed by the federal government (1997: 53.4 million Euro) is the biggest and most important sponsoring institution for industrial research. Subsidies granted accounted for 0.49% of GDP in 1985, 0.61% in 1990, and 1.04% of GDP in 1999. The increasing number reflects the Austrian government's efforts to increase its by international standards – extremely low R&D expenditures. The FFF gives financial support mainly to small and medium companies.

Unlike the EU policy, the FWF and the FFF apply a bottom-up-principle, i.e. funds are distributed to whatever project applies after passing an evaluation of the proposal, without framework programs.

Other financing instruments are the ITF (Innovations- and Technologiefonds/Innovation and Technology Fund), who supports fields of science that are targeted by the Federal Government and recently also aims at improving cooperation between industry and academia in applied research. The Jubilee Fund of the Austrian National Bank (Jubiläumsfonds der Österreichischen Nationalbank) and the ERP-Fund (European Recovery Program Fund) still dating from aids from the Marshall Plan) are further funding institutions.

In academic research (for the FWF) telecommunications was and is not a prime target of public R&D funding. Only 7.3% of subsidies were spent for technical sciences. In applied science (for the FFF) telecommunications is targeted second after mechanical engineering. 13.1% of total budget goes to telecom related projects and 10% of the ITF subsidies (2 mio Euro). At present, the most prominent field of ITF support is for data processing. Telecommunications funding was and is no policy priority in Austria.

4.1.2. Lack of Finance

Austria’s companies finance themselves internally, out of sales, and externally by bank credits. Whereas internal financing (e.g. premature depreciation, investments reserves, "*Investitionsfreibetrag*"...) was the most prominent form of financing after World War II until the late 1970s, this changed in favour of external financing in the late 1970s, that is in Austria mainly through bank loans (Lacina 1991: 231ff). Other means of financing, such as bonds, equities or venture capital, are still very rare.

The Austrian financial system is designed for small and medium firms. MNEs in telecommunications Austria such as Alcatel and Ericsson Austria are stock companies, but the stocks of their foreign subsidiaries are 100% owned by the parent company and not traded at the stock market. 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 is also a stock company but the shares are family-owned to 100%. None of these companies is traded at the Vienna stock exchange.

The only Austrian private company traded at a stock market is 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 chose the Frankfurt alternative stock market because no equivalent existed in Austria and this German market has experienced a hype of technology stock trading since its foundation in 1997. AT&S is also very R&D intensive, and needs the capital for developing a new generation of PCBs. It is interesting to note that AT&S is also the only company on the upstream end of supplier chain 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 (since 1997). Telekom Austria's privatization by emitting

25% of the shares at the Vienna stock exchange turned out to be a flop. Telekom Italia wants to withdraw from the Austrian fixed line network, after having had a take-over (Der Standard, November 10th 2001).

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. The Austrian stock exchange is historically underdeveloped and lists too few assets and too low amounts, it is a "thin market" considered more risky.

The Bond market has been highly regulated till 1987 and was reserved for nationalized industries and banks. Altogether, Austria's financial system is not designed for big private players. But in telecommunications this was less of a hindrance than in biotechnology.

4.1.3. Training and Education in Telecommunications

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 and sometimes to establish development capacities at this location. Austrian basic training can compete with any of the EU - countries. Austria has about 3000-4000 pupils in telecommunications related fields at the secondary level. This amount is pretty stable since the 1980s (before: 2400 in 1975) Telecommunications engineers and technicians are trained in technical high schools, HTL (Höhere Technische Lehranstalt,) and acquire the title of "Ingenieur" At the tertiary level, there are FHs (Fachhochschule - technical colleges/polytechnics) and Technical Universities (TU) which both terminate with a university diploma, that is: Diplomingenieur. At present, technical universities are losing much of their students to polytechnical schools (Fachhochschulen) Fachhochschulen were created only in 1994/95 in order to fulfill EU harmonization principles because Austria's secondary school "HTL

7/98 4,103 students studied electrical engineering at the university, from which only 463 students actually finished their studies, about one fourth of them (111) in telecommunications`For students at technical universities contacts with companies is very weak. Unlike FHs, only a small proportion of diploma theses (about 1/3) are supported by companies (Interview 3).

Fachhochschulen are in contrast extremely popular at the moment. The short duration of studies certainly is the major reason for this trend. In 1999/00, the number of students already increased to 9,600.

The high and increasing demand for telecom engineers means that most HTL graduates (secondary school), especially those from HTLs specialized in electrical engineering, are immediately absorbed by the labor market, that is not only by the Austrian but also by the German one (Interview 16). Austria provides personnel for the German market. It is therefore no surprise that companies "fight" for employees by means of high starting salaries (Kurier, August 29 1998). One of Austria's assets is its good education but lower salaries than Germany.

4.1.4. Regulation/ Deregulation and Standardization

The legal deregulation was definitely the decisive step to lay ground for general transformation of the Austrian telecommunication sector, for infrastructure, services as well as for equipment. Several inefficient services undertaken by ÖPTV and the cross subsidies form the only profitable unit – telecommunication – to the deficit units had to be dissolved. Further, due to former budgeting practices, the telecommunications unit could not keep its profits but had to transfer them to the Ministry (Pachlatko 1997: 213). All these practices, which made the Austrian telecommunication sector anything but competitive, ceased with the new telecommunications Act of 1993 and the succeeding acts.

As a regulating agency, the Telekom-Control GmbH.was established in 1997. Telecom Control regulates the Austrian telecommunication market and the dominant position of several companies on the various market segments. It also regulates the prices Telekom Austria may charge for renting out phone lines (mobile and fixed).

Whereas Telekom Control is in charge of active regulatory tasks, the (former) Ministry of Science and Transport, BMWV is responsible for the establishment of ground rules for the activities of Telekom Control and the legal conditions for the further development of the telecommunications sector. In addition, the BMWV is responsible for representing the Republic of Austria on international telecommunications bodies, such as on standardization matters (bmv 2000). By law, BMWV is the top telecommunication regulatory agency.

The standardization of telecommunication technologies generally falls under the jurisdiction of EU directive 99/5. Anything not ruled under this directive is regulated by national norms and standards such as communication technologies for ships and aviation. In Austria this is taken care of by the ÖNORM. The central organization for European telecom standards is ETSI (European Telecommunications Standards Institute).

Another important institution for international standards is the UN organization ITU. This is supposed to harmonize standards around the world that is to say between North America, Europe and Japan.

Suppliers from small countries such as Austria take the chance to participate to get insights in new developments for future markets. They see ETSI (and ITU) as a forum to exchange information with competitors on the latest technological developments and standards they might to have adjust to (van der Verkens 1998). Whereas Austrian political Actors were never in any position to influence international technological developments,

4.1.5. Technology Policy – The Step Child of Austrian Policy

The lack of any specific support during the digitalization process can be seen as an inhibitor to the Austrian system of telecom innovation.

The post war era up to the 1970s was characterized by import and imitation strategies to catch up with the economic development of West European countries. Especially Chancellor Kreisky favored the big traditional industries, which were oriented toward production but did not rely on R&D (Tichy 1986, Interview 10). For a long time, the dominant attitude was not to take the risk of investing in R&D but simply to import new technologies (Steindl 1982: 64).

Almost all modifications of Austrian technology policy during the last 20 years were induced from outside. In 1989, a "Concept for Technology Policy" was designed defining technology policy as a part of economic, industrial, environmental and structural adjustment policy. The original design suggested to create an agency (Büro für Forschung und Technologie) in order to coordinate research financed by the two major funds FFF and FWF (Die Presse, Sept. 9, 1997, Jan. 15, 1998). Instead, a new committee was founded to serve the party proportion of the ruling coalition. Since the funds were still housed in different ministries, run by different parties, a coherent approach to technology support could not be taken (Der Standard, Jan. 15, 1998).

The institutional responsibility for technology policy on the level of the national government was never clearly designed in Austria (Gottweis/Latzer 1997: 658). Several ministries and agencies housed competence for this policy field. In the 1990s there were the Ministry of Science and Research, the Ministry for Public Economy and Transport, and the Ministry for Economic Affairs. The Office of the Chancellor had some coordinating responsibilities while the Ministry of Finance had to take care of the administration of funds. The divided responsibility is owed to party politics, the social democrats and the conservatives took more care of distributing the power over funds and offices equally than agreeing on a coherent technology policy. Even after the last elections (1999), the disruption of the responsibility is continued, split between the conservatives and the Freedom party (Der Standard, Feb. 14).

There was no particular focus on telecommunication in Austrian technology policy. Until the beginning of the liberalization process, telecommunication policy was either industrial policy (support KASS to keep jobs in Austria and guarantee a functioning telecommunication infrastructure) or budget policy (revenues of the telecommunication unit of ÖPTV were reallocated to cross-subsidize deficits of other state-owned enterprises (Latzer 1997: 672). EU-programs were generally addressing large companies, thus only the Austrian subsidiaries of global players such as Siemens and Alcatel were able to participate.

A new instrument of Austrian technology policy was introduced in 1998, using a strict bottom up approach of organizing new centers of competence (Kplus program). The aim is to improve cooperation between scientific institutions and industry. Out of 13 applicants, five projects were accepted, one of which focused on telecommunications: funded to different shares by the national government, the state governments, and the private industry the Vienna-based "Forschungszentrum Telekommunikation Wien" (FTW/Research Center for Telecommunication) was created in 1999.

Austria's involvement in EU programs developed slowly. Among the four countries compared, Austria has the lowest participation rate in programs such as ESPRIT, RACE and EUREKA. It is also engaged in COST, ESA and EURAM.

In 2000, compared with other countries, Austrian participation in ACTS (see ACTS 2000) (22 projects) was third lowest after Iceland (7 projects) and Luxembourg (3 projects).

Even though there was some internationalization in R&D in Austria, Austria once again lagged behind other European countries (e.g. Finland which also joined the EU only in 1995, showed a higher participation in EU information technology programs than Austria).

Another trend is that Austrian participation in EU programs is no longer dominated by universities but EU R&D is increasingly conducted in companies.

The late recognition of the significance of national technology policy had a negative effect on the progress of technological development in Austria. This path dependency can be felt until today. Even the efforts of the late 1980s and 1990s were half-hearted attempts to focus on some key technologies. Science and technology policy is still as much uncoordinated as it was 20 years ago. Competencies are scattered in several ministries and agencies. The division of labor among the various research institutions, are unclear and there is no central organization responsible for coordinating telecommunication research. Links between academic research at the universities and industries are only lately being support by federal technology policy. The Austrian engagement at ESA and some other European projects was largely a matter of prestige without much spin off for the technological progress of the Austrian economy. Since the accession to the EU, Austrian engagement in EU projects has been considerably low, though some effects on a few companies and research institutes are recognizable. All in all, Austrian technology policy cannot be evaluated as a supportive institution for the national innovation system of telecommunication. Especially compared to the other three countries, the neglect or even absence of such a policy is a disadvantage to the international competitiveness.

4.2. Global or National?

National institutions – not a national system of innovation including the whole idea-innovation chain – play a role even in a global sector. First, they determined historical developments and path dependency. (Siemens Austria research settled in Austria and stayed there because the know how was already there). Second, they provide facilitating and hampering conditions for firms. The Austrian education system facilitated innovations, the Austrian financing system hampers them. Though in telecommunications financing seems to have been a lesser handicap than in biotechnology. The Austrian legal system prevented competition longer than in other countries. This means that global players settled down later than somewhere else and can have created some further path dependency. The lack of technology policy for telecommunications also added to this fact. The low public funding, the missing of a clear technology policy line and the Austrian self understanding that global players had the say explain why Austria's performance is relatively weak in this sector. Austria did not have the Finnish technology escape capacities, the early competition and liberalization that might have induced other firms to enter earlier (but also not need it as urgently as Finland). It did not have the high funding, the huge research centers the good linkages between universities and telecom players as did Germany. And it did not have the Dutch tradition of multinationals and early liberalization. It had solid workers and a good location towards the East not too far from Munich. It offered a sales location opportunity with some already established development and applied research niches more born out of coincidence than of strategic planning.

The Austrian paradox - though it gets weaker - persists compared to the three other countries, because the country size, the geographical location, history and sector specialization and the national institutions differ.

Conclusions

In its decision to fully digitalize the Austrian switching system, the state owned Austrian post and telecommunications company (ÖPTV) was one of the first in Europe. Austria was an early bird but did not catch the worm. It ended as a laggard. It did not manage to develop an own Austrian switching system, but imported technology from Canada and Germany and adopted foreign innovations to Austrian needs. Many small countries followed this strategy.

Until liberalization, the Austrian telecommunications sector was under strong political influence, with a state-owned monopolist and a cartel of the four major equipment suppliers, which partly were subsidiaries of multinational companies.

Telecommunications itself was regarded as an industry that provided many jobs and value added for Austria. These two priorities - many jobs and value added - partly explain Austria's way to a fully digitalized telephone network. The basic problem for the national ÖPTV was the lack of domestic know-how in digital switching technology. Capacities of the domestic actors, ÖPTV, the equipment suppliers and universities or other research institutions, to introduce digital switching technology were practically non existent. The ÖPTV no longer had a research department (it was closed in 1955). The two genuinely Austrian equipment suppliers Kapsch and Schrack did not have sufficient know-how in digital technology and ITT and Siemens, the two subsidiaries of multinational companies, only had some rudimentary know-how through their contacts with the parent company. Both companies were integrated in the parent companies' R&D fields. Thus, proper Austrian research and/or development activities were almost impossible. Even if capacities were there, as for example the program and systems development (PSE) division of Siemens Austria , development was mainly done for the parent company. Universities or other research organizations did not play a role back then.

The size of the country and the almost exclusive orientation towards the domestic market did not allow to generate economies of scale, required for major investments in R&D. One can argue, of course, that Finland is an even smaller country and a world leader of some segments of the telecom market. But it is the exclusive orientation towards the domestic market almost until liberalization that distinguishes Austria from Finland, who had the entire Nordic market with the same standards at its disposal.

Austria's telecommunications market was a closed shop. There were only four equipment suppliers to the state-owned ÖPTV, which assigned contracts according to fixed quotas. Thus it was a fail-safe business for the equipment suppliers and there was no competition between them.

The system decision (digitalization) itself was heavily influenced by political actors, especially by the chancellor, who intervened in favor of Siemens. Thus in the end, even though the licensed system of Northern Telecom (Canada) was technological superior, two systems (from Northern Telecom and from Siemens) were procured. This political influence is no real surprise: the state-owned ÖIAG (Österreichische Industrieholding AG) held 43.6% of Siemens Austria, plus Siemens Germany threatened to stop activities (cut down personnel) in Austria,

Concerning education and training, Austria seems to promote a good and solid basis for medium level, good quality workers and engineers which is certainly one of the most distinctive features. However, the Austrian academic system does not generate enough graduates, especially in technical sciences and it does not set many incentives for extraordinary performance as, for example, the meritocratic US system, where the most talented get more than average support.

This educational system with a good medium-level work-force and a low number of university graduates especially in technical science does hardly foster radical innovations but probably supports the existing practice of traditional incremental innovations or sales improvements.

The lack of a focused technology policy can be seen as another explanatory variable for the low involvement in any innovative activities. Funding was scarce and random-like, without any specific target. Other instruments, besides money, were absent until the 1990s.

The driving force behind digitalization was industry policy, i.e. keeping jobs. The technology policy of the last 20 years (and before) was certainly not designed to change the unfavorable setup of the Austrian telecom sector that impeded innovation.

Social partners were only involved in telecommunications with the creation of ÖFEG. Before that, changes in Austrian telecommunications were determined by labor interests alone.

Analyzing the Austrian policy network, it is – as is typical for neo-corporatist regimes – striking that consumer interests were hardly involved in telecommunications. Also the fact that the Ministry of Economics was not involved is worth mentioning and can be explained by the fact that labor interests only dominated the state owned provider.

Reforms in the Austrian telecommunications sector were mostly induced from outside and mainly followed the "traditional Austrian" way: ”give gas but don't forget to pull the brake”, as the representatives of the Economic Chamber, Kehrer, expressed it in the early 1980s..Also trade unions emphasized the importance of slowness. “The most important person in a bob slide is the one who pulls the brake” as trade union leader Verzetnitsch expressed it in the late 1980s. Reforms take place slowly and changes occur only gradually.

All these factors indicate that not one single determinant can be identified to explain the limited Austrian innovative activities in the telecom sector. However, path dependency seems to play an important role in explaining today's situation For a variety of reasons, Austrian players did not have the capacity to introduce "large technical systems". The question is, though, if Austria should have invented an own Austrian digital switching system. Small countries are perhaps safer in finding niches.

Did Austria find niches or did it become a country where global players open some sales offices. Did Austria become the victim of global players, using its geo-political location towards the East for their sales and marketing subunits, or are there some niches that are prone to innovation?

Some niches have successfully been developed. Austria found some niches such as software development, voice recognition and smart antennas but it did not manage to get such a large niche that it could become an international player (such as Nokia). The two major Austrian firms disappeared in takeovers.

Austria seems to be a laggard slowly finding and developing its niches in telecommunications. It certainly is the least innovative country among the four investigated in our study. But it also seems to be more than a sales office location for global players. Its institutions, in particular its educational system and its potential for cooperation due to the smallness of the country and the smallness of the political and academic elite seem to be its most promising national assets to maintain the Austrian paradox of successful economic performance with little innovation expenditures.

Tables

Table 1: Timetable - Technological changes

Figure 1 and 2: Statistical overview of the main actors of the Austrian telecommunications sector Insert d:\tser\Structure during digitalization.ppf

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Interviews done by Susanne Giesecke, Herman Oosterwijk, Stefanie Rossak and Brigitte Unger in 2000 and 2001

ANNEX I. T3. TELECOM NETHERLANDS

Switching Technology through Five Decades.
Dutch Telecommunications under Change

Herman Oosterwijk

Utrecht University

Country Sector study as part of the final report of the TSER-Project 'National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries'

Table of Contents

Introduction

In the post-war years each country developed its own telecommunication switching system, each with its own norms and standards. Yet, the introduction of digital equipment has changed the European landscape considerably during the 1980s. A minimum of 1.4 to $ 2 billion sales per year was at least necessary to recover the sky-rocketing research investments of new digital exchanges. Some companies could still find shelter in protection of the home market, but is was evident that a shake-out in the telecommunication industry was at hand and only few companies could survive the digital battle of the 1980s. In a 1987 interview Björn Svedberg, then president of Ericsson, predicted that only few companies had the potential to survive: AT&T and Nortel in the US/Canada, two Japanese companies and three European companies, notably Alcatel, Siemens and Ericsson (NRC-Handelsblad, 1987).

By the time of that interview Philips was reconsidering its role in public switching. In the early 1980s it was obvious that Philips was not able to design its own digital exchange. It had tried to upgrade its PRX A system into a PRX D system[1], but fell short in software design. It though to have found the solution in a joint venture with US AT&T in 1983, which had already a digital system operational in the US. Yet, the joint venture APT did not bring the success that was hoped for. The AT&T switching system 5ESS needed far more technological adjustment to fit into the national and Europen system than was expected. Thus, the costs of introduction were much higher than expected. Although this was a severe problem, it could have been overcome if APT had managed to get access to foreign markets. However, this was also much more difficult than expected. APT's 5ESS system was in the race to be the procured by the French national operator and had good prospects, because it held a handful of technological trump-cards. Yet, when it came to crunch, the French operator chose for French equipment. That was the signal for Philips to throw the towel in the ring. It lowered its share in APT to 40% in 1987 and totally withdrew from public switching in 1990.

[1] PRX-A stands for analogue and PRX-D for digital switching

The Problem

How is it possible that this strong multi-national company, which has been one of the few European exceptions able to resist fierce Japanese competition in consumer electronics, was not able to survive in the field of telecommunication? In this chapter we will provide an answer to that intriguing question. We will start with a discussion of historical developments which have led to the specific structure of the Dutch telecommunication landscape as it was to be found in the early 1980s. The *'Philips-story'* in public telecommunication, which started in the post-war years and lasted until the 1990, covers an era with rather close ties between the national operator and the biggest producer in telecommunication. However, Philips withdrawal from public switching was not the end of the Dutch telecommunication industry. Its partner in the joint venture, AT&T (later Lucent Technologies) still has a dominant place in public switching. But also other companies, especially Ericsson, holds a strong position in telecommunication research. The focus of our analysis is twofold: first we will discuss the organisational setup of research activities within companies and between companies. We will also discuss the contribution of the public operator and the knowledge institutes. Subsequently we will discuss the institutional setup, because in our view factors like culture, research funding, the education structure, and rules and regulations are influential factor in the shaping of networks along the idea-innovation chain.

1. Telecommunication under the electromechanical paradigm [2]

The first telephone services started in 1881, when the Nederlandsche Bell Telephoon Maatschappij (NBTM) opened its first network in Amsterdam. Several other companies followed: Ribbink, van Bork and Co., one of the biggest, started telephone services in a range of cities scattered all over the country: Leeuwarden, Deventer, Breda, Delft, Den Bosch, Leiden, Middelburg, Tilburg, Vlissingen and Zwolle. The Enschedesche Telephoon Maatschappij started a local network in Enschede; the Alkmaarsche Telephoon en Goederendienst in Alkmaar and Den Helder; and the Kayser company in Nijmegen. The

[2] The historical chapter strongly leans on J.H. Schuilinga (eds.) *Honderd jaar telefoon, geschiedenis van de openbare telefonie in Nederland*,

first trunkline between Amsterdam and Zaandam was exploited by the NBTM and again several private companies followed. In 1997, using the momentum that was created by expiration of the licences for trunk lines, Government took over the right to exploit long distance lines, mainly to protect its revenues from the state telegraph lines. Changing the rules at the expiration date of the private licences for local networks was also used by municipalities. Amsterdam (1896), Rotterdam (1896) and The Hague (1903) have preferred to build completely new systems, rather than purchase the deteriorated Bell network (Holcombe, 1911, cited in Noam, 1992)). However, compatibility and quality of the local networks still differed considerably and in 1907 the Post and Telegraph service (PT) started to take over the local networks. By 1928, when the name of the national operator was changed into *Staatsbedrijf der Posterijen, Telegrafie en Telefonie* (PTT), it had acquired all but the local networks of Amsterdam, Rotterdam and The Hague. PTT gained full control over telecommunication services when these last three local systems were forcefully incorporated in 1940 during the German occupation in World War II. The 1904 telephone law did not provide PTT with the statutory monopoly, but in practice it has acted as one.

Traditionally the local networks had procured equipment from a range of suppliers. Rotterdam for instance was supplied with Ericsson equipment, while The Hague procured equipment from Western Electric Company. Yet, Siemens and Halske had the biggest market-share nation-wide and PTT had a clear preference for Siemens equipment, especially after a test in the early 1930s with automated equipment, which had proven that Siemens equipment was not only cheaper, but also more flexible than its competitors. As one of the first public operators in Europe PTT decided to automate the whole national telephone system already in the early 1930s. By that time the local networks of Amsterdam, Rotterdam and The Hague were already automated, albeit with the use of a different technology.

Germany has been the most dominant supplier of technology in the pre-war years, not only in switching technology, but also in radio technology. The Netherlands had a special interest in long distance radio-telephony, firstly because of its colonies in the East Indian Archipelago and secondly because its interest in international shipping. In 1918 a group of shipping companies founded the Nederlandsche Seintoestellen Fabriek (NSF), which started to produce radiographic equipment. The dominant technology was acquired from Telefunken, but Philips got involved when it stepped into the production of vacuum tubes, used at the very heart of radio-transmitters and receivers. Initially, also PTT experimented with Telefunken technology in radio transmission, but it also started to build its own powerful transmitters and receivers. It has set up a range of experiments in antennas and long distance propagation and in 1917 it managed to establish a long distance telegraph connection with the East Indian Archipelago. PTT and Philips have more or less competed in radio-technology. Philips was for instance the first to transmit a radio-programme in 1927 to the East, but PTT was the first to establish a bi-directional telephone line in 1928.

Yet, Philip's interest was not so much in telephony. Its expertise in mechanics, needed to build switching equipment was low and the market for switching equipment was already divided between specialised companies like Siemens, Ericsson and the Western Electric Company. Philips rather concentrated on products stemming from its core-business, which was in lightning and the production of vacuum tubes, like for instance the production large transmitters and radio-sets. In telecommunication it used its expertise in transmission; Philips was already before World War II involved in the production of cables and amplifiers to be used in the network.

World War II has left the telecommunication system in a deplorable state. Much was destroyed or heavily damaged. Repair was not easy because PTT lacked the foreign currency to procure equipment from abroad. Dutch PTT has tried to procure equipment from several suppliers, like for instance Albiswerk, a Swiss subsidiary of Siemens, ATEC, BTMC, NSEM and Ericsson, but it had to cancel several orders because of the devaluation of the Dutch guilder in 1946. The main supplier of the pre-war period, Siemens & Halske, was locked off as supplier and its establishments in the Netherlands were regarded spoils of war.

In re-building the infrastructure there was a strong tendency among government and PTT management to procure equipment from domestic telecommunication suppliers, yet, there was hardly any supplier. Only Ericsson and NSEM (former WEC) had small production plants in the Netherlands. In that time and circumstances it was an obvious choice to invite Philips to take over the former Siemens & Halske production facilities. In 1947 Philips stepped into the production of the Siemens F-system, and thus in the production of switching equipment. Initially it started production, building on Siemens technology, but from the early 1950s on, with its own design, which could perform more tasks and at a much higher speed.. This brought some relief, but it did not solve PTT's problems. It was no exception in the post-war years when equipment was all set ready for installation, while housing was still under construction or no staff was available to install and maintain equipment. As a result of the particular setup of operator and telecommunication industry in the 1950, but also as a result of operator's restricted financial elbow-room, system procurement years was a rather uncoordinated policy. The decision in the early 1930s to automate the whole network, using equipment from one sole supplier, was a clear strive for uniformity. It should surpass the five systems that were operational in 1940. However, instead that this number was lowered, it rose throughout the post-war years and by the end of the 1960s there were 17 different systems operational, albeit some with just a local reach. For Dutch PTT it has been a true challenge to integrate all these systems in one coherent operational system, and it has thus truly build a reputation in system-management.

1.1. Actors in electromechanical telecommunication research

The main actors in the Dutch telecommunication research system were Philips and Dutch PTT. NSEM and Ericsson had also research facilities in the Netherlands, but these could be typified as *down-scaled replica's* of the parent company (Chesnais, 1992, p. 272). Both NSEM and Ericsson managed roughly the same line of products as the parent company, with small amounts of product and process adaptation to the extent deemed necessary. In this section we will discuss the role of Philips and PTT separately and then go deeper into cooperation and coordination between these two players. We also will discuss the role of knowledge institutes and universities.

1.2. Philips telecommunication branch

Philips business-focus has always been on lighting, consumer electronics and components. Yet, Philips was not a total stranger in telecommunication. Its first involvement in the telecommunication business was in radio-transmission, where it started to supply the NSF with vacuum tubes, thus building on its experience in the production of light-bulbs. Shortly before World War II Philips took over the NSF.

Vacuum tubes were not only at the heart of transmitters and receivers, but also at the heart of amplifiers, which were used to stabilise the signal in trunk-lines. Philips was, thus, active in the infrastructure, especially in transmission technology, broadcasting transmitters, radio communication systems (fixed and mobile / for land and maritime use), micro wave transmitters and receivers and radar systems.

> Philips has always been a multi-faced company, easily bending over towards customer's demand. It acquired the NSF in 1927, but did not change the company's name and granted the company a considerable degree of freedom. This was not an exception, but intended policy. Philips was a strong proponent of a decentralised approach and also granted its foreign subsidiaries considerable freedom. *Local for local* was the adage. Philips was French with the French, German with the Germans. Management of the British subsidiary once explained: *"We are as British as they come. We employ 65,000 people, we pump millions of pounds into the British economy, our exports for this country are growing and we support institutions in this country to a greater extent than a lot of other industrialists. That our share-holders happen to be located in the Netherlands is almost irrelevant."* (Metze, 1999, p. 66). Thus, Philips was rather a holding company with a range of relative independent subsidiaries than a centralised multinational.

From 1947, when Philips took over the production of the Siemens F switching systems, Philips integrated all telecommunication activities and renamed the NSF into Philips Telecommunication Industry (PTI). The name was changed several times afterwards, especially when it first integrated, but later, hived off defence systems. By 1981 Philips' PTI had five product groups: (I) public telecommunication, (II) new telecommunication services, (III) business communication, (IV) mobile communications and (V) traffic control systems. In 1984 the public telecommunication branch (switching) went into a joint venture with AT&T under the name APT[3]. Philips reduced its participation in APT in 1987 and in 1990 it withdrew totally from public switching. As Philips hived off its public telecommunication and transmission branch into the joint venture with AT&T, it combined the remainder of the PTI with its computer division Philips Data Systems. This did not bring much of a success and the computer branch was sold. In 1996 Philips sold its mobile telecommunication branch to Lucent. The core of the remainder was renamed Philips Business Communication Systems and this is the situation as we know it today..

Compared to other European telecommunication industries, Philips was a late-comer in

[3] APT stands for **A**T&T/**P**hilips **T**elecommunication

telecommunication. Soon after it had started production it found out that the Siemens F system lacked the speed and capacity to meet increasing customer demand for telephony. Philips researcher Professor Uunk[4] invented the U-45 switch with rotating elements that could handle 300 ports per second. This technology was introduced in 1955 and several times improved afterwards. By 1970 approximately 70% of all switching equipment in the Netherlands was based on this technology. Until then all switching and transmission equipment were developed under the analogue, electro-mechanical paradigm. Technology had reached a high degree of sophistication, yet is was clear that capacity and speed were still too limited. Two new technologies, both on the verge of breaking through, might bring the solution: computerisation and transistor technology. In theory a switching system could be designed based on digital technology, using the switching capacity of transistors, rather than to rely on mechanical switches. Yet, the design of a purely electronic switch was a bridge to far in the early 1970s. The supply of full electronic components was still dubious, but, what is more important, Philips did not have the skills to design the software needed for a full electronic system.

Thus, Philips sticked to its known technology and introduced a new range of switching systems based on *reed-relay technology*[5] which was an improvement in speed and capacity compared to old metal-based switching technology. A novel feature in this system was a computer to perform managerial tasks and accounting. From that moment on all managerial tasks could be performed from one central terminal, instead of plugging new subscribers manually onto the system. Next to the fact that this switchboard was faster and offered much more capacity, it demanded a much smaller workforce for operating and maintenance.

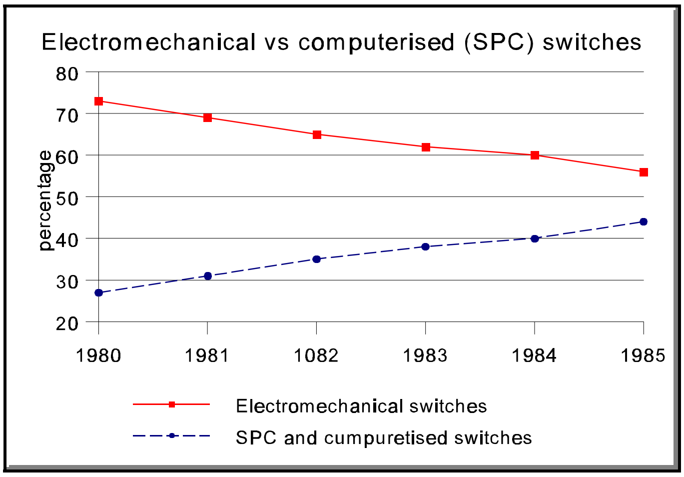
The technological setup of the new PRX switch may have looked outdated at the time of invention, but there were several reasons to choose this path of development. First, Ericsson had already an SPC switchboard operational in Rotterdam and even though Philips was the biggest player in the equipment market, it feared competition. Second, the technology to produce reed-relays was a familiar technology. Philips had build up considerable expertise in glass-technology, especially in light-bulbs, vacuum tubes,

[4] Uunk was associate professor at Delft University for Technology

[5] These were basically vacuum glass tubes with contact point of reed springs, operated by a coil. They had the advantage over classical systems that they were easier produce, easier to install and they had a lower demand on maintenance. Furthermore, reed relays were not liable to wear and insensitive to dust. This new design was a giant leap in performance, but still based on analogue technology.

radiation tubes. The reed-relay was more or less a variation on the theme. Third, Philips was involved in the production of transistors, but it knew that this technology dit not offer the stability that could meet the exceptional high standards of telecommunication engineers. Besides, the production capacity of full-electronic components was still lacking. Fourth, digital technology did not find fertile ground in the mind of Philips engineers and management. Researchers who tried to engage in this new direction were actively discouraged, because Philips main products were all based on analogue technology and leading scientists and researchers did not expect that digital technology would find real solid ground, whether in telecommunication, nor in consumer electronics. And finally, fifth, Philips had a deal with IBM, the then leading producer of computers. The deal entailed that Philips would be the sole supplier of computer components, under the condition that Philips would not step into computer-technology and production. Philips initially kept its side of the deal, but when IBM purchased components from other suppliers, Philips still stepped in computer-technology, although much later than much of its competitors.

Two years after Ericsson had installed its first Stored Programme Control switchboard (SPC switchboard) in 1972, Philips installed its own version of the SPC system after a full year of experiments in 1974. This change of technology had far reaching implications for the Dutch telecommunication landscape. In the post-war years the market-shares of Philips, Ericsson and NSEM (later ITT) had been relative stable, with Philips being the main supplier, having a market share of 70% and Ericsson and NSEM each having approximately a 15% share. At the introduction of SPC technology it was however decided that Philips would be the main supplier of SPC equipment, with a 70% market share and Ericsson the second supplier with a 30% market share. This division of market share was thought to be fair, even though NSEM was rejected as a supplier of public switching equipment. However, it was compensated for this loss with a substantial order for business systems



Afbeelding 1 *Electromechanical versus computerised and SPC switches*
Source: Wielands, 1988/ PTT annual reports

(until then Philips had been the sole supplier of business systems and this equipment could only be purchased through PTT).

Philips' position was clearly protected by this purchase policy. A 70% market share was regarded to be at least necessary to recover development costs and until then Philips had only access to the Dutch market. It was, however, essential to open new markets, especially in sight of increasing development-costs of next generation systems.

Philips has tried to gain access on the telecommunication market in several European countries using its two step strategy, that had worked so well in consumer electronics. The first step; it acquired a foreign company which was already a supplier of the national PTTs. The second step: it gradually tried to introduce its own elements. This two step strategy may have been a proven strategy for many product lines, but it did not work out that way in switching equipment. Philips only managed to sell a few large switching-nodes abroad. It did, however, manage to build up a considerable market share in business communication, telephone sets, broadcasting equipment and transmission equipment. In public switching it broadened its market and managed to get a foothold in Brasil and South Africa. It also acquired, in a joint venture with Ericsson, a five billion guilder contract in Saudi Arabia, but it fell short in entering other markets in under-developed or developing countries. That it managed to get a strong foothold in Saudi Arabia was, because this was a cash-rich country, able to pre-finance the project. Other countries, like Malaysia, lacked similar resources and pre-financing the Malaysian project went beyond Philips financial stretch. This must be understood against Philips financial crisis of the 1980. Another promising contract with Indonesia bounced of due to political conflict between the Dutch and Indonesian government (Metze, 1991, 1997)

By the end of the 1970s it was obvious that the future of telecommunication was in digital technology. Philips undertook a serious attempt to digitalise its PRX switch, but failed. It was not so much a lack of technological skills to develop the digital switch, but when it came to crunch it lacked the capacity, knowledge and skills to write the necessary software. 'High qualified system-developers and software designers were extremely expensive and they could only be found in the US. Technicians just had to prolong analogue technology a little longer,' according to Wisse Dekker, then Philips CEO (Dekker/van Lonkhuizen, 1996, p. 192-193). This has been a far reaching decision, because software was the crucial element of digital systems; 60 to 80 % of development costs were on software. (Roobeek, 1988, p.298)

To survive in telecommunication Philips had to search for a partner. Top-management of the telecommunication branch had an outspoken preference for Northern Telecom (Canada), which was already active in the just opened US market. Conversely, Philips was an attractive partners to Northern Telecom, because it hoped to use Philips as a bridge-head to the European market. Yet, the Philips board of directors decided differently. Gerrit Jeelof, then acting top manager of the telecommunication branch lived by the adage *'think Big...!'* and started negotiations with AT&T, the biggest telecommunication equipment company world-wide. Despite fierce resistance from PTI's senior management and fierce resistance in the board of directors, who feared AT&T's lack of international experience, Jeelof and Dekker managed to shepherd the proposal through the board of directors and the supervisory board and in 1983 the joint venture APT could take off. AT&T brought in a group of engineers and technicians (± 60) and its main asset: the 5ESS digital switchboard. Philips brought in 2,500 employees, housing, equipment, development and sales facilities, the product groups public switching and transmission and -despite the loud protest its CEO Lorentz- its German subsidiary PKI. An interesting fact is that Lorentz some years later managed to free German PKI from the APT deal (for further reading: Metze, 1992, 1997).

The joint venture with AT&T did not bring the success that was hoped for. APT got access to the Dutch market (75% market share), but it turned out to be much more difficult to enter the well protected telecommunication market of other European countries. What was designed as a triumph of synergy, turned out to be a loss-making game, mainly because of three reasons. First, the 5ESS switchboard was supposed to be APT's flagship, but it took much more effort to adjust the system to European standards than was foreseen. Dutch PTT had committed itself to 5ESS equipment and was among the first European operators who decided to digitalise the network. APT's turnover rose 50% in the first three years, but did not break-even. It heavily leaned on sales in transmission technology, in fact, the traditional Philips part. Second, the persistence of national sentiments were largely underestimated. Philips had always managed to be a chameleon, taking the colour of its environment and thus blending in as a national company. Yet, APT was obvious a US/Dutch company and thus a threat to the domestic telecommunication industries. This was even stronger fed by anti-US sentiments. APT's attempt to enter the French market had come a long way, but in sigh of an agreement the order went to the domestic French telecommunication industry. Third, the merger has been a culture shock. PTI researchers were eager to perform on top of technology and put great pride in having one of the most reliable and cost efficient telecommunication infrastructure. That was not the sole achievement of Philips, but Philips contributed considerably to the success.

Collaboration with PTT, its main customer, used to be rather strong. Researchers of both companies knew each other by first name and often cooperated, hardly having secrets towards one-another. All in all, the atmosphere between researchers was rather open, giving researchers a good amount of discretion. The joint venture with AT&T was a cultural clash, with the Americans having an attitude that all good comes from the US. In the words of an interviewee:

'I remember well when the AT&T people came here first. It was a group of experts, all having a brand new passport, because they never had been abroad before. The were accompanies by social counsellors, because the Netherlands, well that was 'underdeveloped territory. Well, those People came in with an attitude as if the Dutch engineers were just a bunch of simple technicians and that has caused a lot of tension, especially because all former PTI senior-managers had left. Even though these were capable people, they disappeared one by one and all with big problems. They were simply not accepted by the Americans. A dramatic different style of management. The Americans had an absolute centralised structure. Consultation with the New Hampshire headquarters was necessary for every detail, even the smallest. We rather used to the opposite and used to have considerable discretion in a -more or less- organic structure.'

The French adventure was the signal for Philips to bring back its share in APT to 40% in 1987, and that marked the beginning of the end. APT was changed into AT&T Europe and some time later Philips decided to bring back its share to 15% and in 1990 totally withdrew from public telecommunication. AT&T Europe continued its activities under the name AT&T/Network Systems International and in 1996 under Lucent Technologies.

The failure of APT has really shaken the fundament of the Dutch telecommunication research structure. Especially the balance between the main players (Philips and PTT) was disturbed. Until then the research organisation of both companies fit together like the pieces of a jig-saw puzzle, but APT centralised approach has put this system under pressure. Decision making in the joint venture was strongly centralised towards AT&T headquarters and cooperation between customer and supplier was greatly disturbed.

1.3. PTT's research establishments[6]

PTT first steps in research were made in the 1920s, in radio-technology. It was strongly involved in long distance transmission and has set up several experiments in radio-transmitters and propagation. It was on top of technology in long distance antenna-design and the Netherlands have been one of the forerunners in radar-technology[7]. Yet, radio-transmission has been a rather isolated activity, detached from operations in transmission and switching systems. Yet, the roots of research in the fixed network are more or less comparable with those in radio-communication. A good part of equipment, like switching nodes and transmission equipment, is designed in industrial laboratories, but how equipment behaves when it is brought into a larger system used to be a matter of trial and error. Technicians at PTT's repair workshop managed time and time again to introduce incremental innovations to enhance the capacity of the system, but, as one improvement could easily jeopardise another, a coordinated approach was needed. This has been the main reason for the establishment of a laboratory for Telephony and Telegraphy (T&T lab.) in the early 1930s. By 1937 the laboratory had 22 employees, among them four engineers. The main task for the T&T lab was to extend the capacity of the network by a range modulation techniques.

The radio-lab and the Telephone and Telegraphy lab, were both part of PTT. A third lab was added in the beginning of World War II. It was the Laboratory for Physical Combat Equipment ,

[6] Much of the data in this section are derived from Dick van de Nieuwe Giessen, Onderzoek en ontwikkeling bij KPN; een geschiedenis van de eerste honderd jaar (1996)

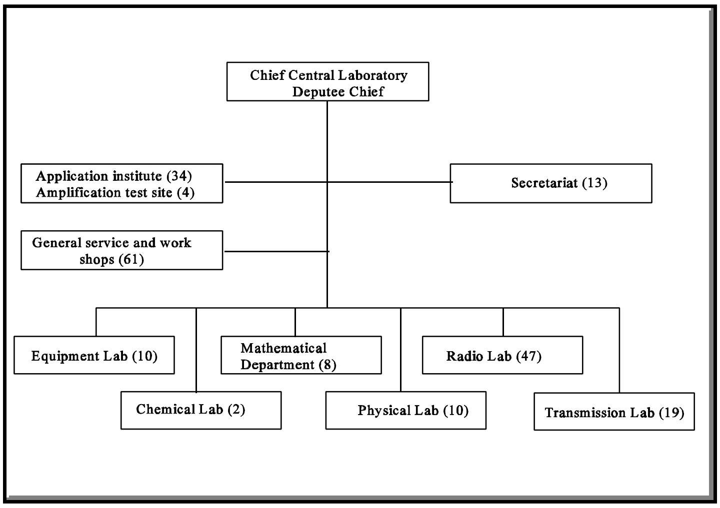
[7] Research done at PTT in close cooperation with Delft university has been of great significance in astronomy, especially when it switched from optical observation to radio-observation. Building on its head-start in radio-technology and antenna-design, the Netherlands could develop into one of the most prominent nations in the field of contemporary astronomy (Schuyt and Taverne, 2000, p. 346).

originating from the Ministry of Defence. This lab had transformed itself into a civilian laboratory during the war. Thus, three laboratories, each with its own direction in research were gathered under the umbrella of PTT, but there were hardly any links between the laboratories. Research used to be a single man's job at that time and included pioneering on the leading edge of scientific progress. However, by the end of the war the first ideas for a central research department were discussed. This department should include the radio-lab, the T&T lab and the defence lab. Yet, soon after the war the defence lab regained independence and the idea of a central laboratory, just included the former radio lab and the T&T lab.

The design of the central laboratory was very much based on the organisational setup of Philips Natuurkundig Laboratorium (Philips NatLab). Its primary task was intended *'to be active in the field of research and to develop new findings and inventions to a basic solution for application in the system.'* (Hooijmans, 1981, p.107). In the first blue-prints of the central laboratory, the core of the lab was thought to be made up of a physics laboratory and a chemical lab. Grouped around the core a transmission lab, a switching lab, a radio lab and an application lab were planned. The design clearly outlined PTTs ambition to be active in the field of basic research. However, this was an ambition too high. According to Hooijmans, even applied research was only a moderate element of the laboratories performance; its basic task was system-development. Thus, in practice, R&D and operations were much closer interlinked, than in the ambitions regarding the Central Laboratory.

This was especially true in the beginning of the Central Laboratory. Radio-technology was concentrated at Radio Kootwijk, which was a small village in the middle of a large wilderness-area. This place was especially suited for long distance transmission, because the place was free of disturbances and interference. Experiments to improve the quality of the system were performed on the spot and, although radio-technology had developed a substantial science base, much was done in a trial and error mode. Switching and transmission research was housed at The Hague. Opportunities for cooperation and coordination between both sectors increased when the former T&T lab and the radio lab were housed in the same building; mutual contacts were much easier now, although the orientation still differed considerably.

The initial design, based on Philips setup of its NatLab gradually watered down. The chemical lab, which was intended to be at the core of the central laboratory had only two scientists by 1950 and it was clear that ambitions were aimed too high at the foundation of the central laboratory. However, even though the reach of research activities was closely related to operations, the interest and motivation of research personnel were very much science driven and PTT was rather productive in scientific publications and had filed many patents.



Afbeelding 2 *Diagram of PTT's Central Laboratory's research organisation*
Source: PTT, 1981

Another interesting feature is that the Central laboratory did not had a special laboratory for switching technology, even though it was intended in the original setup. Here we find an interesting difference with countries like Germany and Austria, which were both aiming at uniformity in the system and thus in system-requirements. The Dutch procurement-strategy has always been to keep arm's length relations with industry in switching technology. The Netherlands has its main supplier (Philips), but next to that two co-suppliers (NSEM and Ericsson). Compatibility-problems, caused by the use of different switching systems were a main field of attention for PTT research and thus, transmission, system development and application were the most important fields of interest.

As research activities grew, the need for laboratory space increased and in 1955 PTT opened a brand new laboratory[8] and the central laboratory was renamed it after PTT's former General Director, Dr. Neher. The Central Laboratory developed most prosperously. In 1947 it started with 112 employees. By 1950 is had almost doubled and by 1956 it had 320 employees. 13% of the laboratory

[8] Again, Philips is used as a benchmark. Usual procedure in the Netherlands is that public buildings, whether they are used as schools, ministries or post-offices were build and supervised by the Rijksgebouwendienst, the State Building Service. Contrary to usual procedure the assignment to design and build the laboratory was given to the same architect who has designed a new laboratory for the NSF, which was renamed in Philips Telecommunication Industry, and a full Philips subsidiary

staff had an academic degree, while 6% had a degree from polytechnics. 29% had a special certificate from the Dutch Radio Society, which was the leading institute in the mid 1950s. The rest 52% had a certificate from the mid-level technical education system, or was still in training. In 1955 the proportion technical staff and non-technical staff was 93 : 7

As stated before, PTT's research achievements were closely integrated with operations and much of research was aiming at solving practical problems. Learning by doing, learning from experience and learning by searching were the main learning strategies for PTT and innovations were for the most part incremental. 'Several generations of telephone technicians have devoted a major part of their career innovation and implementing apparently incremental refinements in the system. These incremental innovations were, however, an absolute prerequisite to handle the growing demand for telecommunication services.' (Van Hilten, 1988, p. 77).

1.4. Universities and research institutes

The Delft University for Technology has been most important for telecommunication research. After World War II it was the sole technical university in the Netherlands, and several researchers from Philips as well as PTT -often company-heros- were associate professors at Delft University. Cooperation between the radio lab and the T&T lab may have been low on the operational level, there were mutual ties though, because the academic circles had their own mores of cooperation and consultation. Delft University has always been in the front-rows of development in radio technology and strongly involved in propagation and radar technology. Still today it is one of the universities with a strong orientation in basic research. For instance, it recently developed the wold's smallest optical switch[9].

In 1954 the Eindhoven Technical university started and in 1964 the Twente Technical university.

[9] The magnitude of such developments is considerable; it is a further extension of the optical system and it prevents that optical signals have to be translated into electrical signals and back again, which leads to considerable savings in energy and it is much faster.

If the magnitude of Delft Technical university is in propagation, than Eindhoven's strength in photonics and Twente's strength is in system-development and mobile communication. However, such labelling might easily neglect the contribution in other fields, which are considerable.
Although the main focus of universities is on basic research, all universities are also strongly involved in applied research. Contrary to many other technologies, telecommunication is not an open field that easily allows for novel combination. 'It is rather an *innovation regime*, which provides the capability of coordination, direction and leadership in the creation of many of the radical innovations that have emerged in the sector. Thus, one may claim that the strong innovation regimes and high R&D intensity of the telecom sector has provided a capability of creating innovations on purpose - for a purpose' (Godoe, 2000, p.1033). The telecommunication system has demanded a substantial system of international arrangements and standards, which makes the system manageable, but these very standards have limited the search areas. Mobile digital communication for instance is closely tied to specific frequencies, but that also limits basic research to those frequencies and here we find an excellent example for such an innovative regime. According to our spokesmen at the universities, around fifty percent of all research is applied research.

2. The 1980s: from electromechanical to digital/optical systems in telephony

In a technological sense the period between 1945 and 1980 has been relatively stable. The Dutch telecommunication system was relatively modern (already in 1962, shortly after Switzerland, the Netherlands was the second European country to have a fully automated switching system) and very efficient The number of lines per employee were the highest among European countries and cost efficiency followed that same pattern (OECD various years). The introduction of SPC switchboards in the 1970s was a leap forwards, but the basic switching technology was still analogue, still electromechanical. However, in the period between 1980 and 1990 several dramatic changes have taken place: 1) the technological paradigm in switching and transmission technology changed from the electromechanical to the digital/optical paradigm. Speed, capacity, quality and reliability increased, while costs decreased considerably; 2) The regulation system changed from a tightly organised and controlled market to more liberalised arrangements; 3) the monopoly of PTT, which had existed for so many years has been broken down. State owned PTT was steps-wise privatised

2.1. Technological change

The first 5ESS digital switchboard, which was the crown jewel in the joint venture between Philips and AT&T was installed in 1985, thus giving the Netherlands a head-start in digitalisation. The real impact and potential of digitalisation came to blossom withe the introduction of optical fibres in the network. These fibres had a much greater capacity and even though the cost per kilometre were higher that the traditional cables, their properties were such that higher investments were justified. Furthermore, optical cables could be installed without repeaters and amplification on every few kilometres and did not demand any maintenance, which reduced costs tremendously. All in all, digitalisation of switching and transmission increased efficiency with giant leaps.

The change from analogue, electromechanical systems to digital, optical systems in the mid 1980s has sparked many developments. It has opened new markets, with an ever increased number of players, with an ever increasing amount of services and an ever increasing integration of technologies that used to be separated fields. Developments in telecommunication nowadays are no longer sparked by inventions in its own exclusive field, but rather by generic inventions in adjacent fields, like computer-science, information technology and electronics. A modern integrated circuit for instance, contains so much elements of all these technologies that it is impossible to ascribe these to eighter of these field.

Yet, the effects of digitalisation were hardly foreseen. Initially industry, but also the public operator, looked at the potential of digital technology through an analogue pair of glasses. In a presentation to an international telecommunication conference, Cor van der Klugt, then Philips CEO, made the next historical overview:

> *'In the 1950s, when public telephony was a conventional industry, like textiles and steel, development costs for an electromechanical exchange were around 10 million dollars, while the expected life cycle was about*

25 years. In the late 1960s / early 1970, when electronic based analogue switching equipment was introduced in the network, system life-time had dropped between 12 and 15 years. Yet R&D costs had increased dramatically to 200 million dollars. The digital system of the 1980s has an ever shorter life-cycle: between 8 and 12 years. Most significant, R&D costs have rocketed to 1 billion dollars or more.' (Van der Klugt: 1987)

Increasing development-costs and shortening life-cycles were expected, but digital technology has proven to be much more flexible than ever expected. Digital technology has become a transmission concept, nowadays with only few tangible assets. The construct of the software to run the system has become the very heart of the system. Hardware has become a platform to run several applications. It is easy to add or delete functions in today's digital technology, while analogue equipment had all the functions embedded in very design of the machine. In research on digital switching equipment the hardware component has decreased to less than 15 or even 10%. The rest is software and this has proven to be a for more flexible concept than ever expected

2.2. Privatisation

The matter of PTT's legal status has been an pinching issue for many years and in 1979 the subject was back on the political agenda again. Several committees have studied the subject during the 1980s. In 1989 the first stage towards full privatisation took place as PTT gained legal independency as a limited liability company, which was followed by full privatisation in 1994, when PTT, which had transformed and renamed itself into KPN, was listed on the stock-market.

The historical setup of Dutch telecommunication was based on private companies, which were granted a concession for a given period of time. The 1904 Telegraph and Telecommunication Act combined the recognition of a licence based system, with a nationalisation clause to bring local networks under government control. The 1915 PT designation act established PT as a government department with a budget that was, however, rather independent from the Ministry's revenues from telecommunication. The PT administration was designated to operate the telephone and telegraph system on behalf of the state, but at the same time in subordination to the minister and subject to budgetary legislation and detailed parliament supervision (Hulsink, 1996, p.222). This construct has always been a pinching issue. PTT lacked independence to act and develop like a real business, it felt as if parliament was taking the driver's seat. Every now and then, this was indeed the case. Even though PTT developed in a prosperous way and generated enough revenues to cover new investments, members of parliament stated that: *'The PTT administration should not be allowed to be an island of prosperity in the sea of misery of our national budget.'* Thus, from a business perspective, PTT was indeed curtailed. It was not allowed to extend the network, even though the waiting list was ever growing; it was not allowed to borrow on the capital market, and thus could not make long term plans. On top of that, its employees were civil servants with relatively low wages. Especially when the economy was steaming up, many employees left PTT to accept a position in industry.

The first moves in the post-war years toward more elbow-room for PTT were made in 1962 when government assigned the Geelhoed committee to advise on the status of PTT. This committee took a pragmatic position between the Ministry's and PTT's demands, but after many discussions its final advice was neglected in 1970. It almost took until the 1980, before privatisation was back on the agenda again. The Minister held out the prospect of a gradual move towards more market conformity and more autonomy for PTT concerning tariffs and investment decision, provided more permanent positive results would be achieved (Slaa, 1987). During the 1980s three committees have advised in this matter. The Swarttouw committee suggested to liberalise the market for terminal equipment and value added services. The provision of the infrastructure, standard-setting, certification and approval should remain the exclusive domain of PTT. The committee Bordewijk/Arnbak suggested to liberalise telecommunication services, but to keep the information transport under the responsibility of PTT. Even though there was more or less consensus on the Swarttouw advise, no measures were taken, due to a change of government. The Christian Democrats and Social Democrats envisioned a retreat of the state from the national economy. Telecommunication was regarded to be of vital interest for trade, transport and finance and the Cabinet argued that Dutch telecommunications should follow developments in the US, UK and Japan: *'Not participating but awaiting the developments abroad may have disastrous consequences for the economic development in every industrialised country'* as was expressed in parliament. This changed the discussion. What used to be a discussion about gaining a relative independent position regarding government interference, now changed into a discussion on privatisation and -in its slipstream, liberalisation.

In 1984 the Steenbergen committee was assigned to: *'evaluate the present responsibilities and functioning of the PTT administration and to propose adjustment in the status, structure, task and supervision of PTT to improve its flexibility, decisiveness and entrepreneurship.'* Already in 1985 the Cabinet published a White-paper in which it endorsed the broad outlines of proposals, integrating the advise of the Steenbergen committee, which was a perfect match with government's general policy on privatisation and deregulation. The White paper encouraged innovation and competition in the provision of telecommunication facilities, while at the same time securing a nation-wide and uniform provision of basic telecommunication services. In order to increase efficiency and market responsiveness, the Cabinet supported the change from a state department into a holding company with a public limited company status and two limited corporate status companies for telecommunications and post, all subject to civil law. This future PTT, with the state as its sole shareholder, should be given permission to negotiate loans on the capital market, to enter into joint ventures and develop a market based wage and working condition policy. Government influence was restricted to the appointment of members of the Supervisory Board (Hulsink, 1996:236).

In April 1986 the proposals were discussed in the Standing Parliamentary Committee on Transport and Public Works and the outlines of the 1985 White paper were endorsed. In December 1987 a package of four bills was introduced in Parliament:

1 The PTT Personnel Bill, including rules regarding the future legal status of PTT personnel;
2 The Telecommunications Bill, replacing the 1904 Telegraph and Telephone Act;
3 The PTT Authorisation Bill, regulating the new role for PTT as a limited liability company and granting it the concession under the new Post and Telecommunications legislation;
4 The Post Office Bill, revising and updating the 1954 Post Office Act.

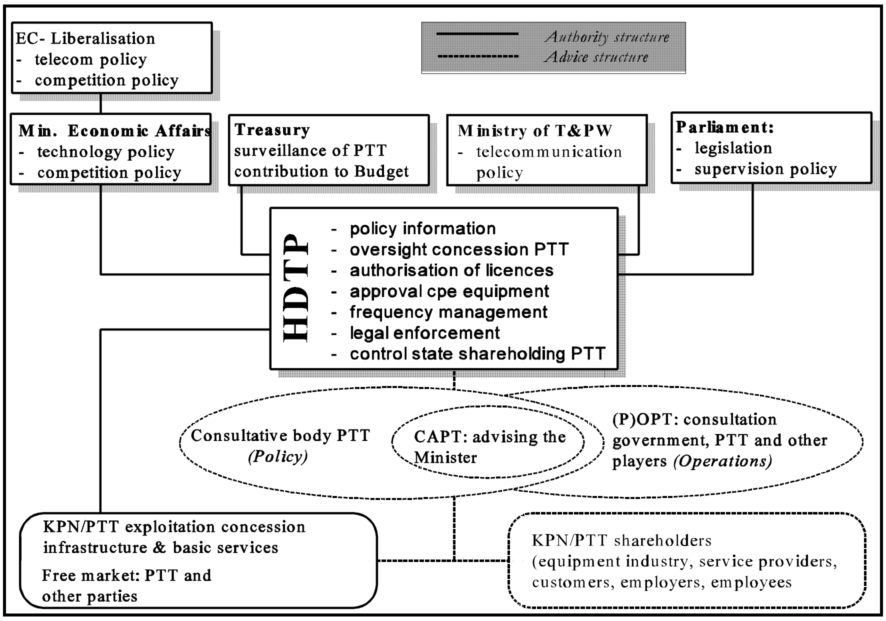
This packet was discussed early in 1988 and most of the Steenbergen recommendations were followed. There was, however, debate about the Committees proposal to split PTT telecom into a public utility company for infrastructure management and a commercial enterprise for services. In the best Dutch tradition parties compromised on not to rule out the legal separation of the telecommunications division, but to postpone the final decision. This would leave PTT time to prepare its internal organisation for a more liberalised environment. As a result the path towards full privatisation was a two step strategy. The first step in 1989 was towards pseudo privatisation with the state as the sole shareholder, however, with legal independence and under civil law. The second step was made in 1994, when KPN/PTT offered shares to private parties. From that moment on the State had a 43% share of all the KPN stock. As of 1989 KPN was the largest Dutch public limited company with a workforce of ± 100,000 of whom 30,000 were PTT telecom employees.

2.3. Regulatory reform

Historically PTT was a governmental body, and as such part of the Ministry of Transport and Public Works, to whom the Minister could give direct orders. The privatisation of PTT had wide implications for the regulatory structure. Until then, PTT had always combined regulatory and operational functions. In the design for a new regulatory structure (largely prepared by PTT), the regulatory tasks, such as standardisation, approval of new equipment, granting concessions, frequency management, legal enforcement, etc. were taken from PTT and accommodated in a new body of the Ministry of T&PW, the HDTP (Hoofd Directie Telecommunicatie en Post), which started in 1988.

HDTP was designed as an executive body that had to integrate several policies: at the European level the general policy on telecommunication and competition; at the national level technology policy and competition policy for the Ministry of Economic Affairs; for the Treasury the surveillance of PTT's contribution to the budget. It also had to prepare legislation and perform policy supervision for Parliament. Being the concession giver, it had to supervise PTT exploitation of infrastructure and basic facilities. HDTP was supposed to be the spider in the web. To embed this structure in KPN's business environment, several bodies were designed, of which some were a continuation or adjustment of structures that already existed before 1989.

The RAPT (Consultative Body Postal and Telecommunications) replaced the former PTT Advisory Council. This committee of independent experts was the advisory body for government on the broad lines of policy, technological developments and Parliamentary proposals in telecommunications. It was also consulted by the Minister for a review of KPN's annual report. In 1992 this Body was renamed CAPT (Commission for Advise on Postal and Telecommunication Policy) and integrated into the departmental Advisory Council of Transport and Public Works, which was an intermediary body between KPN and its stakeholders. The Advisory Council T&PW consisted of representatives of equipment suppliers, service providers, customers (households, small- and medium sized firms, large users and government), employers and employees. Also in 1992 another consultative body was established, especially to discuss operational matters with KPN/PTT and its major stakeholders.



Afbeelding 3 *Regulatory and Advice structure in Dutch telecommunications 1992*

This new design for a regulatory and advice structure has had its shortcomings. What was meant to be a balanced exchange of information between actors, had not only 'teething-problems'; HDTP also was not an equal player for the KPN's power-play. Hulsink summarised the four major shortcomings of this structure: first, KPN/PTT dit not provide clear information needed for proper functioning of the structure. Second, the market was immature and lacked the proper conditions for equal access and fair play. Third, the structure was insufficient equipped for effective monitoring and promoting new entry, innovation and fair competition. Fourth, the new established regime was unable to cope with the demands and requirements of the Internal Market and (other) EC-legislation (Hulsink, 1996: 273). The design of the regulatory structure had largely overlooked the increasing jurisdiction of the European Commission in the field of telecommunication and its regulatory regime was heavily criticised. In order to meet EU regulations, the Dutch government had to liberalise the markets of mobile telecommunication, satellite and data-services, and certain national arrangements concerning tariffing, frequency allocation, VAT, resale of capacity, number planning, etc. The Dutch governance regime which was characterised by retreat of the state, had trouble in coping with the detailed system of regulations set by the EU. To solve this problem a new, independent regulatory body was founded next to the policy making and operational units in HDTP. This was set up as an independent body, dealing with overall supervision of the telecommunication sector, acting as a referee between contending market players and the policing of market behaviour. This agency was modelled like the Anglo- American autonomous administrative bodies, based on expertise and impartiality, thus breaking the Dutch tradition that such bodies need to be based on participation, consultation and accommodation. This body is called OPTA, the Independent Post and telecommunication Authority

2.4. Liberalisation

Privatisation of the national operator has been a precondition for liberalisation of the telecommunication market. Until then, all telecommunication equipment had to be purchased from PTT (officially). However, customer demand had already changed during the 1970s and 1980s and the liberalisation of the equipment market in 1989 was a logical step, allowing new parties to enter the market. This was a big success, because several new companies for end-user equipment and business systems could enter the market . In fact, even before 1989 there was an increasing supply of equipment, not only because of increasing customer supply, but also by PTTs own purchase policy. In 1984 it had decided to purchase switching equipment from APT and Ericsson, thus shutting off NSEM (later Alcatel). Forced by parliament, it compensated NSEM's loss by adding NSEM business-systems to its product portfolio, thus allowing customers more choise.

In 1991 several tele-information services were liberalised, like for instance satellite and video services. From the late 1970s PTT had offered new services like data communications, videotex and electronic mail. Technological progress had enabled these services, yet growth stagnated because fixed line telephone services had reached a point of saturation. PTT's experiments in Videotex failed to reach a big audience. KPN/PTT did not manage to organise a good match between broadcasting, information suppliers and publishers, who were responsible for the experiment. In 1990 the videotex experiment was hived off to Videotex Nederland VTX, in which KPN/PTT had a 30% share. In 1994 the experiment fizzled out, when important users decided to step out of this heavily funded project.

Anticipating the liberalisation of the infrastructure market, government assigned the Zegveld committee in 1985 'to investigate the possibility and desirability of an integration of the two separate local infrastructures (Telecom and CaTV) into a single one, controlled by PTT and to give policy recommendations on its implementation.' (Zegveld Committee, 1986). The committee advised in favour of harmonisation into one broadband network to be controlled by PTT. It was especially the Union of Dutch Municipalities (VNG) that opposed, because local interest were made subordinate to PTT. Furthermore, PTT's plea for a centralised and exclusive exploitation was contradictory to EU legislation, which was based on open network provision. In 1993 government decided to liberalise the cable regime as of 1994, and new entrants were free to offer interactive applications and data-services. In 1995 network provision was liberalised and in 1998 the liberalisation of voice telephone services finished the liberalisation process.

2.5. Emerging markets

Liberalisation has opened markets and many new companies have entered the market. KPN Telecom has build up its Lambda Network and also several other operators have invested in the building up of fully fledged or local network. Research of the Ministry of T&WM reveals that companies have invested approximately six to eight billion guilders in the infrastructure. The Dutch infrastructure is known to be the most reliable networks in an international comparison [10] (Minez, 2001).

KPN is still the most dominant player on the Dutch telecommunication market, despite the entrance of several new players. In the consumer market for international telephony it has a 85% market-share, but also in market segments it has the lion-share; fixed to mobile for instance between 80 and 95% and local telephony between 90 and 99% (Opta, 200).

Usually new telecommunication companies first try to get access to large business and industry. For that purpose large local infrastructures are build, build in the Amsterdam (south-west) area, with big companies for a variety of financial and business service and Internet-companies as the main customers. Recently many of these companies have extended their market to small and medium sized companies, retail and private consumers. The Netherlands had already a good starting position, because many cable companies had already a dense network structure for television. In recent years these networks have been upgraded and extended for bidirectional telecommunication services.

The table below gives an overview of the Dutch telecommunication operators in 1999

[10] The Netherlands is compared with the following countries: Australia, Canada, Germany, Finland, France, Japan, Singapore, the UK, the US and Sweden

	Services						Markets				Infrastructure		
	national telephony	international telph	IP-services	Lease-lines	Data comm	Carrier services	Consumers	SME	Large comp	carrier resellers	backbone	private supply	
KPN Telecom	•	•	•	•	•	•	•	•	•	•	•	•	Telecom companies with a fully fledged infrastructure
UPC/Priority Telecom	•	•	•	•	•		•	•	•		•	•	
Casema/ Dutchtone	•	•	•	•	•		•	•	•		•	•	
Castel/Palet	•	•	•	•	•		•	•	•		•	•	
Eneco			•	•			•	•	•		•	•	
Multikabel			•	•	•		•	•	•		•	•	
Palet Kabelcom			•	•	•		•	•	•	•	•	•	
Zekatel			•		•		•	•	•		•	•	
AUCS		•	•	•	•	•			•	•	•		Telecom companies with a limited infrastructure
Carrier One		•	•	•		•			•	•	•		
Colt Telecom	•	•	•	•	•		•	•	•		•		
Enertel	•	•	•	•		•		•	•	•	•		
Equant			•		•				•		•		
FCI						•				•	•		
Global crossing						•				•	•		
Global One		•	•	•	•	•			•	•	•		
GTS	•	•	•	•	•	•	•	•	•	•	•		
Interoute		•	•			•	•	•	•	•	•		
Level 3 Com			•	•				•	•		•		
MCI Worldcom	•	•	•	•	•	•		•	•	•	•		
MLL Telcom				•		•			•	•	•		
RSLCom.Delta Three	•	•	•		•			•	•		•		
Schiphol Telematics	•	•	•	•	•			•	•		•		
Sonera			•	•	•		•	•			•		
Storm						•				•	•		
Telenor	•	•		•	•	•			•	•	•		
Telfort	•	•	•	•	•		•	•	•		•		
TMI		•	•	•	•			•	•	•	•		
USA Globallink		•	•			•	•	•	•	•	•		
Versatel/Svianed	•	•	•	•	•	•		•	•	•	•		
Viatel	•	•	•	•	•	•		•		•	•		
WorldxChange	•	•				•	•	•	•	•	•		

Axxon	•	•			•			•					Telecom companies without an infrastructure
Bermic Telecom		•					•	•	•				
Hilf Telecom	•	•					•	•	•				
Ocean	•	•			•		•	•	•				
One Tel	•	•					•	•	•				
Primus Telecom	•	•					•						
Scarlet Telecom	•	•	•		•		•	•	•		•		
Switchtrack	•	•						•	•				
Talkline	•	•						•					
Tele 2	•	•					•	•	•		•		
Telediscount		•					•						
Teletik	•	•			•		•	•	•				
Transnet	•	•					•						
Triple S	•	•						•					
Unitel			•		•			•	•				
Vocalis	•	•					•	•					
LogiCall Telecom	•	•	•				•	•					Agents
OptiTel	•	•			•			•	•				
Interxion						•				•			

Dutch Telecommunication operators in the market for fixed telecommunications
Source, TNO/STB 2000

An interesting feature of telecom developments in the Netherlands is that many developments are cable-bound. This is not surprisingly because the Netherlands traditionally had two dense network-infrastructures (telecom and CaTV) with excellent broadband properties. Telecom companies have recently invested to upgrade the networks for bidirectional purposes. Especially in broadband and cable Internet the Netherlands has reached high shares of penetration.. The table below lists the results for a selection of countries in various technologies. The Netherland is leading in most of the cable bound technologies, whereas Finland is leading in mobile transmission technologies

Country	Broadband 1999 [a]	Broadband 2002 [a]	Cable Internet 1999 [b]	DSL 2000 [c]	WLL 2002 [d]	WAP 2000 [e]	GPRS 2001 [e]	UMTS 2002 [e]
Netherlands	*1.5%*	*13.5%*	*6.7%*	0.3%	3.0%	3.1%	4.2%	1.2%
Germany	0.1%	7.5%	1.0%	*0.7%*	*14%*	1.8%	4.5%	0.4%
Finland	0.3%	9.4%	0.9%	0.2%	13%	*5.2%*	*7.7%*	*3.2%*
France	0.2%	6.9%	2.0%	0.2%	8.0%	3.4%	2.4%	0.3%
UK	0.0%	9.5%	0.0%	0.1%	4.0%	3.8%	3.6%	0.6%
Sweden	0.2%	8.9%	0.4%	0.2%	9.0%	4.9%	3.4%	2.5%

a) Proportion of households with a broadband connection b) Consumer cable Internet connection as percentage of consumers with an Internet connection c) DSL connection as a percentage of the total number of telephony connections d) WLL connection as a percentage of the total number of broadband connections e) Proportion of the total number of mobile subscribers

Source: IDC, DSL, Cable and FWA, 2000

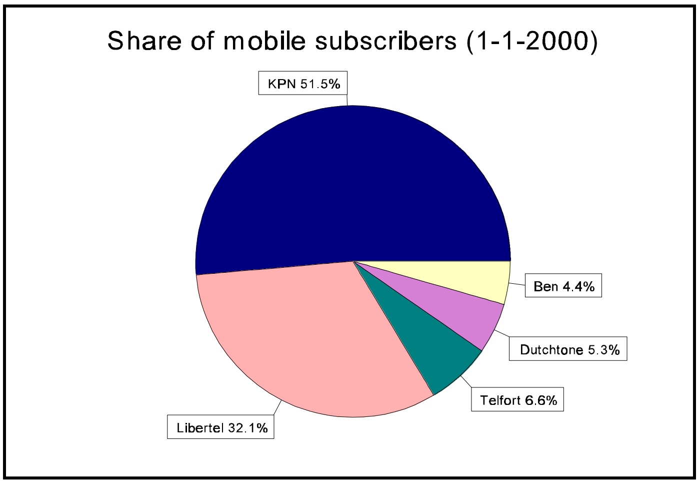
The development of mobile communication started relatively late in the Netherlands. This was partly caused by a hesitant and protective government, insufficient awareness of the economic benefits and the positive effects of competition upon overall productivity and efficiency levels (Slaa, 1993). KPN/PTT has been relatively slow to realise the market potential. The reason for this are manifold: bad marketing, poor quality of service, lack of price differentiation and a go-it-alone strategy regarding sales and service provision (Hulsink, 1996:259). Until 1993 KPN/PTT was the only retail outlet for mobile telecommunication. In 1994 KPN/PTT offered a more flexible tariff structure and varying combinations of subscription, thus anticipation competition. In 1995 a duopoly was established in cellular communication with MT-2/Libertel as the second contender[11]. By that time it had already taken more than two years to reach a parliamentary agreement concerning the legislative proposals to allow competition between KPN/PTT and a contending cellular operator. In 1992 the Ministries involved in decision making agreed on an entrance fee for the two GSM providers of 40 million guilders. However, after being informed about the prosperous prospects, the Treasury demanded a rise in the entrance fee to 500 million guilders. The Ministry of Economic Affairs, backed by organised business was strongly against, because it regarded the burden too high for an infant industry. Also it believed that it would threaten te competitive position of the Dutch service industry in general.

The opening of the market demanded an amendment of the 1989 telecommunications Act. KPN/PTT strongly opposed these liberalisation proposals, arguing that the country was too small for one operator to earn back investments in digital as well as in analogue technology. These arguments were somewhat dubious, because at the same time KPN/PTT started to upgrade its analogue network and also started the roll-out for the digital network. These and several other disputes on privacy, fair competition, access

[11] Five consortia were bidding for the second GSM licence: **Mobined** (RABO, Getronics, Bell South, LCC, Schiphol Airport) **GSM Nederland** (Deutsche Telecom Mobil, De Telegraaf, RCC, GSM Bouwcon, Fortis AMEV) **MT-2/Libertel** (ING, Vodaphone, Vendex, Internatio Müller. LIOF) **Nedcell** (Telecom Finland, Lacis) and **NL-Tel** (ABN_AMRO, Airtouch/PacTel, C&W, Heidemij, Nuon, Radio Holland Electronics, NIB)

charges and inter-connectivity demanded solutions, but have taken considerable time to be solved. Decision making about the opening up of mobile communications (GSM) has been characterised by slow responsiveness and neglect from the side of the government, tactical manoeuvring from the side of KPN/PTT and delay caused by interdepartmental clashes and legal-administrative dismissal (Ibid:260).

1999 has been the year of the definite break-through in mobile telecommunication with an average growth of 97% in one year. It has changed the Dutch position from a relative laggard in the penetration of telecommunication into one of the frontrunners. The impressive growth is partly explained from the market entrance of three new operators. Telfort started in September 1998, Ben and Dutchtone in February 1999. The two biggest players,KPN mobile and Libertel, both having a market share bigger than 25% are acknowledged 'players with considerable market-power' by Opta. This entails that both operators are entitled to offer non-discriminating interconnection on their networks. On top of that both parties have to grant access to parties which do not have a network of their own.



Afbeelding 4 *Market shares of the five operators in mobile communication (1-1-2000)*
Source: Opta, 2000

3. Organisation of knowledge in telecommunication

3.1. General research structure

R&D is often regarded to be the backbone of the innovation structure. The Dutch research structure has been made up of three different research systems: universities, research institutes and private enterprises. Compared to other OECD countries the Dutch level of R&D expenditure is still below the OECD average (2.12% of GDP vs. 2.21%), but above the EU average (1.83%). A striking difference is the relatively low share of R&D expenditure by private enterprises (55%) compared to the average of OECD countries (69%), and a relative strong position of state funded research through universities and research institutes.

Private R&D is strongly concentrated at the large multinational companies. 57% private R&D expenditure is concentrated at only five companies[12]. Among them Philips, which on its own already takes a share of 26%. The ten 'big spenders' account for 75% of all research expenses. Among the big spenders we find Philips (26%), Lucent (3%) and KPN (2.5%), while Ericsson also has a considerable share (1%) (Minne, 1997).

Telecom and informatics accounts for 8.1% of R&D labour years in technological sectors, which is about 3,050 employees. Ericsson employs ± 1,250 people in R&R, Lucent Technologies also ± 1,250, KPN ± 500, and the cable industry ± 50.

Public R&D is performed at universities and public research institutes. It differs from the private sector not just in its source of finance, but also in its orientation. Approximately one/third of all R&D done by research institutes, and fifty percent done by

Euler Institute for discrete Mathematics and its applications	Mathematics
Graduate school polymers	Related field
Research institute Materials	Related field
Advanced school for computing and imaging	Related field
Communication Technology: Basic Research and Applications	Technology
Delft Institute of Micro-electronics and Submicron technology	Related field
Institute for programming and algorithm	Mathematics
Graduate school MESA+, materials, technologies and systems for the information society	Info-tech
Graduate school for Information and knowledge systems	Info-tech
Telematics Graduate school	Technology

2 *Graduate Schools related to telecommunication*

[12] Figures 1995 supplied by CBS/Minne, 1997

universities, is oriented towards basic research, while this is below 4% in private R&D and still decreasing (CBS, 1999). Philips R&D director Schuurman stated in a 1996 interview: 'Philips research is for the prototypes, the technical science; not for the Nobel prize.' (NRC-Handelsblad 31/08/1996). Dutch universities R&D accounts for 0.58% of GDP in 1997, which is a marked difference with the EU average (0.39%) and the OECD average (0.37%). Around 2,100 scientists in technology were employed by the universities in 1990. This number increased to reach its top in 1994 (± 2,550), but then it decreased again to 2,250 in 1997, where it tends to stabilise. (CBS, VSNU, OC&W). The number of scientists in the natural sciences is gradually decreasing from around 2,050 in 1990 to 1,950 in 1997.

The most advanced research efforts are organised in graduate schools, usually involving more than one university. Of the 113 graduate schools, 10 are involved in telecommunication. Two of them, with a specific technical orientation and also two have a mathematical orientation. The other six are active in direct related fields of electronics or information technology.

The public research institutes TNO and the Telematics Institute account for 250 man years, which equals ± 10% of private expenditure in labour years.

However, the size of the telecommunication research sector is low compared to other countries, but its scientific impact is high (Ministry of Economic Affairs, 2000, p 27-28)

3.2. Organisation of research within companies

3.2.1. Organisation of the idea innovation chain

Telecommunication equipment in the Netherlands was basically purchased from three multinational companies. Philips was a multi national company, NSEM was a full Standard Electric subsidiary and Ericsson was a full subsidiary of Swedish LM Ericsson. It is tempting to put all the multinational companies in one box, but there are differences. We recall Barré who has analysed how large multi national companies have internationalised their research activities by the creation of international innovative networks. He distinguished three distinct strategies:

1 *Home based R&D and local adaption networks,* in which the firm has centralised most of its R&D efforts in the home country. The role of subsidiaries abroad is limited to adapting the product to the local market conditions;

2 *Networks based in host countries,* in which R&D activities are decentralised to the subsidiary, because the subsidiary has the size and capabilities to take responsibility for innovative functions, for certain product lines or technological areas;

3 *Division of labour networks,* in which the centre of innovation is located where capabilities to participate in the innovation process are best. The various sites are complementary and there is a division of labour.

Technical capabilities	*Industrial capabilities*	*Strategy*
strong	strong	1
strong	weak	2
weak	weak	2 or 3

3 *Country's technological and industrial capabilities and their preference for international innovative networks*
Source, Barré, 1996

A country which has a considerable strength in both industrially and technologically, will usually adopt the first strategy. A country with a considerable technological strength, but with a weak industrial record will rather opt for the second strategy. It will buy technological strong subsidiaries, which have the scope and size to perform research independently, which is a choice for the second strategy. Countries which are weak both technologically and industrially will have a preference for strategies two and three (Barré in Meeus and Oerlemans, 1999, p. 122)

Philips has always leaned on the first two strategies, but with a preference for the first . As discussed before, the adage was to produce *'local for local'*, but the Philips subsidiaries in host countries have always used and experienced considerable freedom (which was an enduring source of tension in the Philips organisation). In consumer electronics it was no exception when a particular radio or TV-set was sold under many different brands and in many different shapes. In telecommunication we basically find the same situation. The core of Philips' research was its NatLab, which had an excellent reputation in scientific circles for its basic research. However, German PKI and Dutch PTI, both full Philips subsidiaries, had (or better; took) quite a lot of freedom and were able to surpass the NatLab researchers time and time again. Philips was known for its fragmented structure and there used to be

hardly any links between divisions, even if their fields were related. Philips computer-branch and telecommunication-branch had no mutual relations whatsoever, even when they worked under the same management. PTI for instance rather preferred to developed its own computer-applications than relying on the skills of its colleagues of Philips Data-Systems. Innovation at Philips used to be organised as a linear process, with each department adding its own peculiarities, yet, without questioning if that should lead to a better marketable product. The creation of synergy by the combination of adjacent skills was an exception, even though Philips has started several projects. Also
Philips Business Communication Systems used to work in this linear pattern of innovation, but radically changed it innovation policy in recent years. Especially in sight of IP technology, which is based on Internet Protocols, it tries to involve customers in the very first steps of design. Demonstrators are tested on the spot at customers' premisses and is an iterative process between customer, sales-people, researchers and product-developers. Philips has thus changed its linear approach in a more synchronised approach [13].

Ericsson used to be a follower of the first strategy. Switching equipment was designed at the Swedish headquarters and Ericsson's Dutch laboratory adjusted the equipment to local demands. However, as the range of products increased, Ericsson bended over towards strategy two. The standard telephone set, for which Ericsson was the co-producer, was a typical Dutch design, with only remote involvement from headquarters. The Dutch Ericsson research laboratories already had a good reputation within the Ericsson organisation and it soon developed into the leading research lab for several product lines world wide. The Dutch Ericsson laboratories have for instance pioneered with cordless telephony and were the inventors of what has become the DECT standards, which is now the international standard for in-house cordless telephony.

NSEM was a follower of strategy one, and was basically just involved in adjustment to Dutch

[13] The break-up of established research rules has caused a major shift in orientation. Researchers had to leave their save 'castle' build with soldering iron, oscillators, ohmmeters, resistors and integrated circuits. Instead, they had to meet 'people' and they were confronted with new questions: 'What if a customer wants to know about a price?' or 'What if he has a stupid question?', and 'Should I ware a tie...?' These questions were not so relevant in his contacts with PTT researchers, because, then, both parties spoke the same language.

standards. Yet, whereas Philips and especially Ericsson changed towards the second strategy, NSEM changed towards strategy three. Yet, this is not so much the result of a policy of the Dutch establishments, but rather the result of a series of mergers and take-overs, finally leading to the foundation of Alcatel. Initially, this merger had an over-capacity in research, and it is currently reshuffling its research structures. It is now concentrating important business-lines in specific research labs. It has concentrated switching research in Italy, speech processing in Austria and in this process the Dutch research lab is assigned to be active in system-management.

AT&T changed into Lucent Technologies and used to be a typical example of the first strategy. But, as most other telecommunication industries, its scope of research has broadened, thus changing towards the second strategy. Research, especially in software is an international business, and the Netherlands has a relative large share of that research, especially in middle-ware applications. Research mainly concentrates on switching (voice, data, video and multi-media applications), transmission (especially optical transmission), wireless applications, business systems and call-centres. Lucent is a strong supporter of entrepreneurship in research. It stimulates researchers to pick up new ideas, and challenges departments to look ‘what’s cooking on the other side of the fence’. Yet, it is difficult to organise cooperation between sales people and researchers; each department perceives research subjects in different mind-frames and it is difficult to adjust so that they really communicate and look for solutions.

Other firms like Siemens, Nokia and Nortel have become active in the Dutch market since the liberalisation, but have only limited research capacities in the Netherlands. The reach of research is mainly directed toward collecting customers’ wishes as an input for the product-development department.

A general trend, which also can be observed in the companies described above, but also in the latter three, is an increasing tendency to involve customers in R&D activities.

This mainly concentrates on the design of features in business-systems (also call centres), fixed line and mobile telecommunication. Each business system has its own user-group, where problems, suggestions, complaints and new ideas are discussed. This gives industry the opportunity to scan the market in a most efficient way. The industry will only build new features if there is enough customer-demand. The same structure we find in mobile communication. However, the user group is not the final customer of a hand-set, but the mobile operator, which offers a range of services to customers.

PTT research constitutes a story on its own. PTT used to be very active in telecom research and had a renown research groups, with a specialisation in network and system-management. Basically, PTT's research was technology oriented. However, as soon as the first contours of privatisation and liberalisation emerged it was clear to see that the infrastructure and services should be separated and the tendency in the 1980s has been to hive off technological research to give more room to research in service-provision. This was put in effect as soon as PTT entered the first stage of privatisation in 1989. Then KPN continued this process and several departments were hived off, especially to Dutch industry.

In short: the idea-innovation chain, which used to circle around the basic technologies in telecommunication (switching and transmission) has broken up in a multitude of products and services. The more a certain product or service is subject to customer demand, the more the innovation process is organised as a synchronised process, involving all the phases of the idea-innovation chain and with numerous feed back-loops. Yet, in the innovation processes regarding the technological heart of the system, whether it is in transmission, switches or components, the setup of the process is still rather sequential. However, customer demand is increasingly important and all telecommunication companies try to keep in tough with contemporary developments, especially in Internet technology.

3.2.2. Flow of knowledge within the company

The classical telecommunication companies used to be typical examples of a machine bureaucracy with its strong division of labour and unit differentiation, in all forms, vertical, horizontal, line/staff, functional, hierarchical, and even regarding status (Mintzberg, 1979, p.319). Innovation was regarded to be a linear process. The core of innovation was supposed to come from extended basic research activities and most telecommunication companies had sophisticated basic research capacities, with AT&T's Bell-

Labs as the shining example. These laboratories were not only important as the breeding ground for new ideas, but also as a training facility for executives. A common strategy is to hire talented engineers in the research department, and after a few years in research, where they could learn about all the different aspects of the company, they were appointed in executive function. This career path had a large degree of predictability. Yet, the changes that were sparked by digitalisation, and especially by the success of mobile telecommunication has led to a shortage of telecommunication engineers. All companies are fishing in the same pond and all are looking for the real big fish. Mobility has increased, not only within the firm, but especially between firms. Long term labour-contracts based on loyalty are becoming exceptions; job-hopping is the word. Firms regret that because continuity is under thread, but also favour this development, because there is still so much to learn. Researchers bring ideas, solution and information from other companies. They also export knowledge to other companies, which makes cooperation easier.

3.2.3. Recruitment of personnel

Attracting personnel has become a pinching matter. Head-hunters scan for talented scientist at universities and have offered them contracts, even before graduation. Most companies have changed their strategy. A practical year is a good selection instrument and companies seek to cooperate with universities and polytechnics. The Internet has become the medium to advertise new jobs. There is an increasing trend towards internationalisation and English is surpassing Dutch on the shop-floor. Companies employ a multitude of nationalities and are increasingly eager to offer talented scientist the opportunity for promotion and training.

3.3. Organisation of research between actors

3.3.1. Cooperation between companies

PTT/KPN and Philips used to have developed close relations in the post-war years. The research departments fit together like pieces in a jig-saw puzzle. The basis for cooperation was a fluent division of labour. Philips' main interest was the design and production of equipment and PTT brought equipment together in the telecommunication system and was, thus, much more interested in the properties of the system. This complementary system fitted like hand and glove and there is even reason to believe that cooperation among the two companies was even stronger than cooperation within each company. These close relations did not exist with other suppliers, especially in the field of switching. Ericsson and NSEM (later ITT, later Alcatel) provided equipment off the shelf and equipment just had to be adjusted to national standards.

The close relation between national operator and national industry was broken up at the founding of APT. It was clear that APT's technological management was dominated by AT&T. Decisions were no longer taken on management-levels easy accessible to other parties, but in AT&T headquarters in the US. APT did no longer had the characteristics of a national industry and all relations between operator and industry were at arm's length. APS thus took a similar position as Ericsson and ITT (later Alcatel) in adjusting equipment to national requirements.

However, digital technologies offered new prospects for the telecom-industries, both in the fields of (end-user) equipment as in the development of new services. Ericsson grabbed that opportunity and extended its research-efforts to several new field, especially cordless telephony, short range mobile transmission systems and system development. Lucent specialised in middle-ware applications, thus building technological platforms for new services. Cooperation between partners gradually increased, especially through the research projects of the Telematics Institute.

Close relations did not only exist between operator and national industry; it has also been the case with other companies, as for instance with the cable industry. Before the introduction of optical fibre, the cable industry was organised in a cartel-like structure. This system was broken up when BICC, a UK based company, started a price war in the early 1980s [14]. The stable structure with only few players, notably NKF, Draka, TKF, Philips and Pope, was shaken up and it has led to a wave of mergers and take overs. Draka took over NKF and Philips' Optical Fibre[15]. Beldon (US based) acquired Pope and TKF remained independent. Draka developed into one of the three leading cable companies in Europe (next to Pirelli and Alcatel).

Cooperation between the research department of the national operator and the national industry was relatively high. Patents, stemming from public research at the operator were granted to Dutch industry and the cable industry has benefited from that research. Cooperation between industries was also high. Cable company NKF, which has always been the technological leader in the cable industry, invited TKF to join in production of optical cable, when its own production capacity was lagging behind demand. Exchange of knowledge was obvious, especially since the cable industry was well aware of the fact that the national operator would never choose for just one supplier. Thus, although the market was shaken up, it ended in more or less (informal) cartel-like structure again.

Research in low tech telecommunication industries is mostly applied research and product development. Yet, the number of people working in the sector and involved in R&D is so small, that relations are rather informal, which provides an easy exchange of knowledge. It is also stimulated by the cartel-like structure, which minimizes risks in competition.

[14] Liberalisation in the UK started much earlier than in the Netherlands.

[15] Philips Optical Fibre is a good example of a specific Philips research and innovation strategy. Promising new ideas could be commercialised in a -more or less- sheltered environment. As soon as it proved to be a viable option and could stand on its two feet, the plant gained independency. Successful examples are to be found in optical fibre, but also in lithography for integrated circuits (ASML)

3.3.2. Cooperation between universities

Cooperation between the technical universities is liable to two rules. On the one hand each university tries to develop their own domain, which distinguish them from others; on the other hand they try to join forces, to get easier access to research funding. The technical universities have some joint project, of which COBRA is one of the larger. COBRA is the acronym for Communication Technology: Basic Research and Applications and it involves 150 scientists from the three technical universities. It develops research in three areas:

1 broadband telecommunication and multi-dimensional telecommunication networks;
2 design technology for networks and network modules;
3 physics and technology of strategic materials and devices.

The COBRA projects has a range of research groups, some aiming at integrated programmes, but other towards high capacity systems, flexible networks and local networks. It involves semiconductor physics, cooperative phenomena, physics of surfaces and interfaces, solid state theory, solid state chemistry and materials electronic components, technology and materials, organic chemistry, glass technology, electronic devices, photonic integrate circuits, electronic signal processing, digital information processing systems, electro-optical communication systems, radio-communication, design technology and transmission systems and technology.

We took this example, first because it is edge-cutting research in the field of telecommunication, but second, because it well expresses the technologies involved.

This project combines the work of 150 scientist, but similar inter-university groups are active in other fields of telecommunication research. The COBRA project is certified as one of the six Top research Schools in the Netherlands.

3.3.3. Cooperation between academia and industry

Digitalisation has boosted cooperation between industry, but also between industry and academia. The Netherlands did not have an independent research institute in telecommunication: its public research was performed at universities and at the operator. But as the range of activities increased and especially when fields of several technologies began to overlap (telecom, information technology, computer science), an initiative was taken to establish a new research institute, especially on the interface of these fields. The initiative was taken by the Telematics Research Centre at Twente University and the name of the new institute was the Telematics Institute. The idea for such a research institute fell in fertile ground and government, knowledge institutes and industry participate in the institute's basic funding (± 60%). The rest of the budget is supplied by the organisations which participate in research projects or other parties who have in interest in a particular strain of research[16].

The Telematics Institute has become a platform for the development of research-projects in which several partners have an interest. Take for instance the Friends project, which is about the creation of a platform for new services. Lucent Technologies, TNO, KPN research, CTIT (Twente university) and the Telematics Institute participate in the projects. In the Video over IP we find IBM, TNO, NOB (broadcasting), Surfnet and the Telematics Institute. Many other examples can be given, each with its own subject and parties which have a specific interest in the subject.

Some companies have close ties with academia. Philips was the big promoter of the Eindhoven University of Technology in 1954 and currently it is building the Philips campus. Many Philips scientists were trained at Eindhoven university, and some of them return there as associate professor. Several senior scientists at KPN research and TNO have a part-time professorship. Recently Ericsson has started to sponsor a university chair at Twente university. Also the chairman of OPTA, which is the independent supervising agency in telecommunication, has a professorship at Delft university. Yet, despite this networklike structure only few companies in ICT hardware which brought new products on the market cooperate with universities and research institutes (ECIS, 2000/Ministry of Economic Affairs, 2000)

Despite activity and cooperation, the general Dutch performance in the field of ICT research is low, although the quality of this research is high. On the scientific impact in computer-technology the

[16] These are not only the traditional telecommunication companies. Insurance companies and banks for instance, strongly depend on electronic transactions and have great interest en coding and encryption. Also multipoint telecommunication, as for instance in broadcasting, in participating in several projects.

Netherlands ranks second (world-wide), and in telecommunications it shares the third position with Germany, immediately after the US and Finland (CWTS, 2000).

However, quality of research may be high and cooperation between academia and industry may seem to have developed along many (informal) lines; in an international comparison of companies, which cooperate with knowledge institutes in innovation processes, the Netherlands ranks only last. The table opposite lists the share of all innovative companies, which cooperate with knowledge institutes.

Country	University	Research Institute
Finland	40	25
Sweden	21	12
Germany	15	14
EU average	14	13
UK	13	21
France	11	8
The Netherlands	10	9

4 *Share of innovative companies that have cooperated with knowledge institutes in innovation projects*
Source: ECIS, 2000

3.3.4. Cooperation in Networks

The introduction of digital technology in the network has led to an increasing differentiation of technologies, each demanding a high degree of specialisation. These developments could not be mastered by the tradition arrangements, and a range of new cooperation activities were set up. Philips is an excellent example when it stepped into the joint venture with AT&T in an attempt to get access to digital switching technology and especially software-design. Other companies acquired knowledge by market based relations and licenced new technologies.

Hollingsworth and Boyer have listed cooperation forms to the degree in which they are ruled by self-interest or rather constrained and informed by (social) obligations (Holingsworth and Boyer, 1997). Actors who are mainly ruled by self interest coordinate their various specialisations in vertically integrated firms. Their have no relation whatsoever to external partners, and thus keep knowledge safely sheltered within the company. This has been the classical situation in the large telecommunication firms. They supply the whole telecommunication system and produce all equipment in-house, including components and semi-finished products. Digitalisation has put this system under pressure and specialised firms have developed which offer specialised services and products to other actors along the idea-innovation chain. This is for instance the case in the component-industry, where specialised firms discuss the properties of integrated circuits with the large telecom companies. This is not purely a market-relation, because some, or even a considerable degree of knowledge is discussed between partners and thus exchanged. An even further reaching form of cooperation is to be found in networks, joint ventures, strategic alliances and other forms of inter-firm relations. These arrangements are rather based on shared interests than purely shaped by self-interest. These relations demand trust between actors and actors have constrained their mutual behaviour by obligations towards each other. This is rather a cooperation whereby actors, basically on an equal basis join forces and competences in sigh of a specific goal. Networks provide a much better base for the sharing, exchange and transfer of knowledge than vertical integrated companies or market based relations do.

The Netherlands has always been known as a network of networks and working relations in the Netherlands have always been rather informal, rather based on network-like relations than on hierarchy and with limited power distance between management and workers. Researchers know each other, often by first name and many interviewees have expressed that if you visit two or three conferences, you know most of the people. Also companies have developed strategies to keep in touch; they organise meetings, invite other companies to have a look in the kitchen and are involved in joint research projects. They thus are active in the setup of channels for knowledge exchange.

Cooperation between companies in the pre-competitive phase of an innovation process is high. As mobility between companies has increased, people have extended networks, which they sometimes actively use. Several interviewees have pointed to the fact that researchers are not so much interested in strategies or tricky games. They enjoy the technological discussions with other engineers with the same interests[17]. Often they have studied at the same universities, know the same professors, have been in the same student-organisations. These ties are strong and persistent and help to bridge differences

[17] The telecommunication engineer is a prisoner of his own skills. Developments in telecommunication are so fast that it demands a considerable effort to keep abreast of new developments. A joke among university professor is that graduation-parties of telecom students are a little weird, because the person in whose honour the party is held is missing, because he has to catch up with the latest developments.

between companies.

4. Institutional environment

In the previous section we have discussed the organisational setup of research activities in the Netherlands. Yet, the organisation of research activities is not only the result of rational choice. It is also, albeit more indirect, influenced by a country's institutional setup. How is research financed? Is there a good match between the education system and the need for skilled personnel? Is government offering favourable conditions for research, and are the institutional arrangements to bridge the gap between academia and industry? And rules and regulations; do they provide the necessary room for development, or do they put constraints on research activities. Furthermore, what is the role of culture? Do the Dutch have a specific way to overcome differences of opinion? Do they have a sense of eagerness towards technology? These more indirect questions will be dealt with in the section below. We will start this discussion of some cultural traits that guide behaviour in social relations and subsequently move to subjects like research structure, finance, education, government policies, and rules and regulation.

4.1. Culture

Compromising and networking are key in a characterisation of the Dutch. Conflict is usually solved in compromises in which all parties equally benefit. The Dutch are known to be modest people, showing little awe for authority, and they are usually informal and egalitarian. Modesty is regarded proper behaviour; only sports and folklore can generate high spirits. Sharing in the victory of sports-heros feeds feelings of national pride and chauvinism. The roots of this corporatist society, with its eagerness to avoid the sharp edge of conflicts, can be traced back in history. First, the impact of feudalization in the Dutch maritime provinces was more limited than in the eastern and southern provinces and far less than in neighbouring countries. The maritime provinces were hard to reach and peasants have always been free from feudal ties and obligations, already from the twelve's century on. Instead of developing into a agrarian feudal society, the Netherlands gave room for cities to develop and with them specialisation into trade and other commercial activities. Second, its geographical position has stimulated its skills in shipping and the Netherlands has always had an international orientation. It also developed a range of supporting activities, like the production of ropes, barrels, sails, nets, casks, and of course shipbuilding (van Iterson, 1997, p. 51). Third, the Dutch way of managing large scale projects were primarily based on peer review. In drainage and land-reclamation projects special boards (heemraadschappen) were assigned with flood control and dike maintenance. As the Staten General (the legislative body) took over the supervision of these large projects it provoked tension between the regional 'heemraadschappen' and the central legislative body. Negotiation and compromising has solved these problems and the two bodies each have their own discretion. Plessner (1974) has argued that the Dutch, in the winning of peat bogs, in the putting up of dams and dikes, and in the regulation of water via drainage canals, learned to do teamwork in a systematic way. Fourth, large companies like the West India Company (VWC) and the East India Company (VOC), which was the world's firs limited liability company and the largest multinational trading firm in the seventeenth and eighteenth century and West India Company, were managed by a group of 'Heeren' (gentlemen), each representing the interest of a specific region (Zeeland, Delft, Rotterdam, Hoorn, Enkhuizen and Amsterdam) The managing formula in which especially the Amsterdam and Zeeland votes were very powerful, was compensated by their role in operational and controlling task. Top-management thus operates in teams of equals, promoting the interest of stakeholding parties rather than exclusively those of owners. Yet, the traces of corporatism do not all date back from the sixteenth and seventeenth century. A nationally distinct socio-institutional phenomenon, known as 'Verzuiling' (pillarization) has strongly influenced systems of networking and compromising. Protestantism has been the dominant religion in the young republic, but in the Netherlands it developed in a plethora of doctrines, denominations and sects. In the nineteenth century the Roman Catholics and non-confessional groups (esp. socialists) emancipated and joined the public arena, yet each group in its own 'pillar'. Since neither of these religious and ideological groups has gained absolute power in any domain, coalition forming was the only way to come to decisions and to find steady governance (Iterson, 1997, p. 57).

Apparently the few large capital-intensive Dutch multinationals do not seem to fit the picture. They prefer to operate as independently as possible, or have only loose subcontracting relations with firms 'below the waist'. Taylorist work systems, with job fragmentation and managerial coordination of complementary processes are highly developed, but the separation of managers from workers is much lower than in comparable units in the Anglo-Saxon world or in France or Belgium. There are numerous accounts of the low power distance managers and workers in Dutch enterprises. The management ethos is one of aversion against overt display of power or hierarchical differences (Lawrence, 1991, p 128-35, Iterson, 1997, p.59). Persuasion power is most important, closely followed by expertise. The Dutch manager has to be a problem solver, but not without consulting peers or lower hierarchical levels. Above all, he is expected to nurture group relations (ibid).

Joint responsibility, egalitarianism, networking and consensus thus dominate teamwork in the Netherlands. What on first sight seems to be a strict division of labour is often much more interlaced, just below the surface. The division of labour for instance between Philips and PTT may seem well organised and the result of rational choice, but both sides are bending over towards each other just below the surface. Different interests between actors is usually rather solved as *'partners'* than as *'parties'*.

4.2. Research funding

Traditionally the technology oriented telecommunication companies used to have fixed budgets for research. Philips devoted a fixed percentage to R&D and the performance of its NatLab used to be an important element of Philips corporate identity and reputation.

Research at KPN was also a fixed budget, which was basically generated by PTT's tariff-structure. Interviewees at the PTT/KPN explained that each new director has touched the issue of cutting budgets for research, but within days they were all convinced that research was an important intangible asset, important from a strategic point of view, but also as the bearer of PTT/KPN's scientific reputation. At Lucent and Ericsson we find similar high regards towards research and development.

The big industrial enterprises used to have close relations with banks and used to be mainly credit based companies. PTT was fully depending on state-financing. However, digitalisation, with in its slipstream the process of privatisation and liberalisation has shaken up the blankets. Former PTT, now KPN developed a growth strategy. In the process of privatisation it gave out stocks, which could support this growth. Yet, this new system of finance proved to have serious disadvantages, especially when the technology-stock-market collapsed. The question is to what degree this change from credit based systems to capital market based system is boosted by digitalisation, or rather that it has been an autonomous development, nicely fitting in neo-liberal market developments. In Philips, which used to have high regards to *stakeholder- value,* strategies were changed in favour of *shareholder-value* (Metze, 1997, p. 240), thus shifting the balance from a credit based system towards a more capital-market based system. The same is basically true for PTT as soon as it was privatised in KPN. In the best Dutch tradition it had close relations to banks, but in 1994 when it gave out its first tranche of stock, followed by a second issue of stock in 2000.

In this booming field of ICT companies with high shares of R&D, which started in the second half of the 1990s, venture capital was gaining importance. Although the development of relatively new instruments in the financial funding structure, such as seed capital, funds supplied by business angels or venture capital has been relatively slow in Europe, the Netherlands has accepted these instruments relatively quick. In 1996 the UK, France, Germany and the Netherlands accounted for more than three/quarter of all European venture capital. Yet, contrary to the US where venture capital funding of computer related companies is high, in the Netherlands it only accounts for 7% of venture capital in 1995 and just 5% in 1996. These new financial instruments are reaching the stage of maturity in the sense that the use of these instruments is more than an exception.

Public research institute funding has developed along two lines. TNO, the Dutch organisation of applied research, was only indirectly involved in public telecommunication. In the field of telecommunications it was mainly active in defence systems and radar technology. Research in public telecommunication systems gained importance in the latter half of the 1990s especially because public research tasks, that used to be performed by PTT/KPN were no longer the field of a privatised telecommunication operator. Most of the tasks were transferred to TNO. Yet, TNO, which used to be a fully state-funded organisation has gained importance in contract research, thus earning the revenues to grow in size and strength. Many of the customers, though, are government bodies, like provincial or local authorities.

The Telematics Institute is funded by the Ministry of Economic Affairs, knowledge institutes and industry in its basic funding. On top of that, funding is supplied by the participants in research projects.

4.3. Education

There is a fear among policy makers that the knowledge base in (exact) science and technology is eroding, because young people prefer a career in the service oriented sector, management or other economic sectors than in technology. This might easily affect the innovative and competitive capacity in the telecommunication sector. A mutual concern for government and industry is how to persuade young people to start a career in these sectors.

The biggest challenge seems to be how to enhance the attractiveness of careers in science and technology. One strategy to stimulate young students' interest in technology is the foundation of the organisation AXIS to stimulate the attractiveness and efficiency of science and technology. Government, branch-organisation of employers, education institutes and the organisation of job-centres, all participate in this project. The organisation AXIS, founded in 1997, should be a platform where ideas are exchanged on *'how to stimulate interest in exact science.'* (AXIS is funded with 40 million guilders for the period between 1998 and 2002). The fear for erosion of the science knowledge base is widely felt.

The total number of students has risen until 1993; there after it started to fall. In science and technology the numbers have also fallen and the share of university graduates in electronics has gradually decreased from 2.55% in 1980 to 1.17 % in 1995. From the late 1970s on, new academic courses have started in informatics. These were organised by the faculties of mathematics as well as by the faculty of technology. The first students graduated in 1983, and, since then there has been a steep increase until the end of the 1980's. Yet, from 1993 on the number of informatics graduates is also under decline. There are two explanations for the decrease of students in both electronics and informatics. One is that the demographic situation has changed; the *'supply'* of eighteen and twenty-six year-old's is simply smaller than before. The second explanation is that there is a growing interest for disciplines that concentrate on behaviour, society and culture, and this has been a steady line since the 1950s. These disciplines are specially popular among female students. The influx of female students in these fields also explains why the share of students in science and technology has fallen.

The biggest decline in science and technology student share was between 1960 and 1980. Since then the percentage of male students in sciences and technology is more or less stable at 30%. For female students, this number lies roughly at 11% and is also stable.

A similar exploration in the higher vocational training system reveals even more dramatic changes, but this is mainly due to a gradual extension of the system. On average, 32% of all male students takes courses in science and technology, for female students this is 6%. Also these percentages are rather stable over time.

In a 1998 'popularity poll' within the technology sector, technical informatics ranks fourth (8.6%) behind architecture (18.4%), mechanical engineering (11.6%) and civil engineering (9.9%) in. In 1990 it also held fourth place. Within the field of natural sciences, informatics is stable on third place (15.9%) behind biology (28.5%) and pharmacology (16.2%) Electronics ranked second in 1990, but has fallen since. In 1998 it ranked seventh behind the earlier mentioned four disciplines, technical business administration and management (8.2%) and industrial design (7.1%).

In higher vocational training the ranking has been even more dramatic. Electronics fell from first place in 1990 (21.4%) to third place in 1998 (10.9%), and lost almost half of the number of students. It shares third place now with informatics, that came from the fourth place in 1990 (6.8%), but, contrary to electronics, in informatics there has been a sharp increase of students. (CBS, several years)

The often discussed decline of interest for science and technology can partly be explained from autonomous demographic developments and partly from the growing popularity of academic courses in behaviour, society and culture, and their special attractiveness for female students. Yet, on the whole, the share of students for science and technology is rather stable over the last decade. On a lower level of aggregation it is clear to see that the interest for electronics is falling. The decline is especially felt in the telecommunication sector, because employment has sharply increased. Liberalisation has opened new markets which has resulted in an increasing demand for engineers and technicians. Thus, the heart of the case is not the decreasing interest in exact science and technology, but rather an increasing demand for high-skilled personnel. Al in all, discussions about the decline of exact science and technology seems to depend on the context for the discussion. If it is true that further economic growth (solely) would depends on new high-quality technology, then there is reason for worry.

4.4. Government technology policy

A strong belief in scientific progress as a base for prosperity was widely spread, especially in the post-war years. The support of scientific research was one of the pillars of Dutch technology policy in the 1950s and 1960s. By the end of the 1950 Dutch research expenses amounted 470 million guilder. Government funded 20%, industry 80%. By 1973 total expenditure on R&D accounted for 3.2 billion guilders, which was 2.4% of the national income. (Schuyt, Taverne, 2000:122). Technology-policy was basically aiming at creating favourable conditions for industrial development, no matter the type of industry. It was an advocate of the support of R&D investments, and the instruments for an active support of technology and innovativeness were gradually broadened. The biggest contribution was visible in research efforts to scale up industrial sectors and agriculture, in standardisation and automation of production processes, and in increasing R&D efforts and rationalisation of management and organisation technology. These processes have best been synthesised in the chemical industry, which has become a major economic sector in the post war years.

The Ministry of Economic Affairs was and still is responsible for industry- and innovation policy. After the prosperous set-up of a research infrastructure in the 1950s and 1960s, closely linked to strategic economic sectors, it gradually changed its strategy into supporting depressed industries, which were hit by the economical crisis of the 1970s and 1980s. However, the results of this strategy were meagre. Government came to realise that industrial sectors should have a strength of their own to survive economic crisis and the Ministry withdrew from its supporting policy in the mid-1980s to concentrated on its core business: *the creation of elbowroom for free market development and promotion of the innovative and adoptive capacity of industries and services*. Since the 1990s the emphasis is again on the creation of a good industrial climate that offers room for companies to adjust to new markets and technologies. From that moment on support of business in distress is only acceptable in exceptional cases. *Knowledge* is the pivotal word in this new approach and the lion share of the instruments are pointed toward the stimulation of technological innovation.

The heart of the Dutch industry-policy is:

1 *to adopt a favourable policy towards promotion and stimulation of the adoptive- and innovative capacities of industries;*
2 *to present no more blueprints or interventionist sector policy;*
3 *generic support of industry;*
4 *to support competition, by taking away imperfection and (inter-) national disturbances in competition and to convert into cash the external effects of knowledge and technology;*
5 *to be dynamical and flexible and to be evaluated on the effects that is has brought.*

A analysis of the strength and weaknesses of the Dutch innovation system reveals on the strong side that the Netherlands has a strong position in public R&D, an average position regarding the number of researchers; the attractiveness of a knowledge infrastructure for companies; the share of innovative companies; and innovative expenses (non R&D). On the weak side we find, however, a weak position in the closeness to the market of public research; the share of companies with (in-house) R&D; R&D (expenses) in the private sector; and the share of innovative products in turnover (Minez, 2000).

Imperfect market conditions have created a range of instruments, some effective and others less effective. The main attention in industry policy, is drawn towards strengthening the system of R&D. The societal and economic yields of a strong position in R&D demands a forceful incentive policy towards (industrial) R&D. It is acknowledged that financial investments in the input-side of R&D activities is not enough. It is only seldom that companies innovate, while just relying on their own strength and qualities in today's network economy. Besides, technological changes and the costs for development are speeding up, while product life-cycles are getting shorter. The ability and will to co-operate in research and develop is critical for companies. As a result, companies have become interdependent within clusters of related technologies and within chains of production. Strategic co-operation, such as joint ventures and partnerships are crucial. Co-operation also helps to spread risks and costs and helps to limit the time to market. Co-operation is not only promoted between companies, but also with and between universities, research institutes and other partners. Next to financial investment in R&D (input) and marketable products (output), attention should also be devoted to diffusion of knowledge (throughput).

The Ministry of Economic Affairs has regarded ICT as a spearhead of economic activity. Its ambition is to be part of Europe's leading group on the electronic highway: the Netherlands as the *digital delta*. The Ministry of Economic Affairs aims at monitoring the situation on five issues:

1 the telecommunication infrastructure;
2 knowledge and innovation;
3 access and skills;
4 regulation;
5 ICT in the public sector.

It is especially the Ministry of Economic Affairs that has invested in ICTs and not the Ministry of Transport, Public Works and Water Management (TPW). The reason for the division of labour can be traced to historical reasons. The preparation of telecom policy used to be a task of Dutch PTT, officially under the responsibility of the Ministry of TPW. The privatisation of PTT put back responsibilities at the Ministry, however, without the man-power and funds. The Ministry of Economic Affairs traditionally had the highest research expenses and used to be the booster of economic development. However, both Ministries aim to support the creation of networks and it is a given fact that the Ministry of Economic Affairs has more funds to do so than the Ministry of TPW.

4.4.1. Financial instruments

The total amount of money payed by government in the context of R&D promotion in technology has amounted to 943 million in 1997. The most popular instrument was the WBSO (Law on support of R&D). The purpose of this law is to promote R&D by granting firms a 40% discount on salaries payed to R&D personnel for the first 150,000 guilders, and an additional discount of 17.5% for salaries payed for R&D personnel with a maximum of 15 million guilders. This law has been especially popular among small and medium sized enterprises (SMEs). Still, 26% of the budget of this instrument was consumed by firms with more than 1000 employees. The telecommunication-sector has benefited relatively little from these instruments. Eight percent of WBSO money (roughly 50 million guilders) was found in the electronics-sector, of which the telecommunication is a part. (CBS, 199:154-162)

4.4.2. *Non financial instruments*

The set of instruments used in T&I policy is broader than the ranges of financial incentives. The Ministry of Economic Affairs has strongly promoted innovation and research activities by monitoring promising projects, promoting bench mark studies, the organisation of congresses and seminars, giving out brochures, research reports, etc. Even though the effect of these activities is hard to measure, it helps to build an innovative mind-set and helps to set the research agenda. Information and Communication Technology (ICT) and (modern) Biotechnology are two spearhead-sectors of the Dutch economic policy. In ICT, the focus is mainly on the potential of E-commerce and its applications in Dutch business-life, but also on multi-media development and applications in education. There is a strong drive toward the promotion of start-up companies and the Ministry of Economic Affairs participates in several initiatives.

4.4.3. Twinning: an example of creating an entrepreneurial environment

Twinning Business Partners	
Arthur Andersen	Accountancy, tax & business advice
Ernst and Young	
Giga Information group	Technology and management advice
Houthoff Buruma	Legal Services
ING Bank	Financial Services
Int. Data Corporation	Market Information
Meridian technology Marketing Europe	Marketing-Consultancy agency
Monsterboard	Career Network
Sun Micro-systems	Network Computing
WorldCom	Internet and Telecom service

An interesting example in ICT is 'Twinning'. The concept of Twinning is to promote start-ups in ICT by making available (venture) capital, housing, organisational support, advice and providing access to existing business networks. Young ICT entrepreneurs who have a viable idea and a business plan can get support for a given period of time. Support is always a combination of money, facilities and advice. The entrepreneurs can always rely on the expertise of people who have acknowledged seniority in business and these 'mentors' also help to open and exploit networks. The Ministry of Economic Affairs has strongly supported Twinning, but now, as it can stand on its own feet and is supported by established entrepreneurs, business angels and venture capitalists, it has withdrawn from the initiative. Twinning has centres in Amsterdam, Delft-Rotterdam, Eindhoven, Twente, and it also has a foothold in Silicon Valley, in a combination with TNO-Multimedia, KPN Research, Amsterdam University and NV Rede.

Networking is key in the Twinning initiative. In the table some firms are listed that offer their service under very favourable conditions to Twinning companies. This is of course of mutual interest. The Twinning companies gain, because they are able to develop in the most efficient way. The advising companies gain, because they have the best position to stay in touch with edge cutting developments and technologies in ICT. This is also the case for business-suppliers.

Twente University has a special programme for students with an entrepreneurial spirit. It offers them work space, and a one year grant to setup a business. These students can use laboratories and equipment outside office hours. If their company is a success, they have to pay back the grant. If it fails, it is regarded bad luck. Twente university offers these students also coaching on the managerial level, help in contact with financial institutions, etc. (TOP programme)

Twente University and the Science and Business Park thus offers a range of facilities for academics who want to start a business. The programme mentioned above, the Twinning programme, office space in housing projects and the stimulating environment of a range of companies and research institutes on campus as well as in the Twente Business and Science Park. Here one can also find supporting institutions like for instance the Chamber of Commerce.

5. Conclusion

Dutch efforts in telecommunication have been impressive, especially in the 1950s and 1960s. It started on the remains of outdated technology, but soon managed to catch up developments. Philips switches were known to be very reliable and a fine product compared to others in the same market. However, Philips was not a telecommunication company in its bones. It was rather an industrial holding for lightning, components and consumer electronics. Even though it has well performed in telecommunication equipment, it did not have a place in a top ten ranking of telecommunication manufacturers, which it did in several other fields. This had its effects on the telecommunication segment. Philips deal with IBM in the 1960s not to step into computers on the condition that it would be IBM's main supplier of components, has strongly affected its performance in telecommunication. Being the main supplier of Dutch PTT in switching equipment, it had to behold how Ericsson installed its SPC switch, without having a ready answer. It took another three years to develop the PRX computer aided system.

An interesting question is if Philips had made the right choices in technology. Indeed, it was challenged by Ericsson, and it answered effectively with the design of its PRX system, but the concept was outdated, in fact at its introduction, not because of its shortcomings or lack of quality, but because of the emergence of digitalisation. The PRX machine was in fact a redundant step in the process leading from electromechanical towards full digital systems. Yet, to remain competitive in the market, Philips had to invest in digital technology, after it had invested so much in the development of the PRX system. This made the costs hard to bear.

Yet, its ambition to penetrate the world market seemed promising after a five billion guilder deal with Saudi Arabia, but the technology it supplied was getting outdated because of the introduction of digital technology in the US. In sight of the large development-costs and the small and protected European market, it stepped into the joint venture with AT&T, which had already developed a digitalised switch. It was a promising combination, AT&T technology and Philips skills in marketing and market penetration. The experiment soon failed, firstly because both cultures were incompatible, secondly because Philips management has left the scene just before or just after the joint venture and thirdly, because there was no economic yield from the experiment. The economic potential of the joint venture became bare to the bone as French PTT granted an order for switching equipment to Alcatel, despite APT's favourable properties. It was clear that telecommunication still was a protected market, which was hard to penetrate for a Dutch-US combination (or better European-US combination).

PTT has had a solid performance with high aspirations and a relatively large workforce in research. It has developed a balanced co-existence with its suppliers, but never lost its independence towards industry. It was knowledgeable in the field of network development and network building and it thus could meet industry as an equal partner.

The strength of the Dutch research system can partly be explained by its close relations between several actors. In the electromechanical era this has been the case for Philips and PTT and in recent years this is the case for a multitude of companies in the development of services, application, features and (especially) E-commerce. Close relations between relevant actors are on the one part encouraged by social factors (for instance education), but on the other by an extensive system of bridging or intermediary institutions. These provide an independent platform for (even competing) businesses, to cooperate for a given time, a given budget and a given subject. This makes it easier for companies to engage in joint research. The type of cooperation is open and informal, however, with a more distant attitude toward strategic and economic yield. The intermediary structures are based on mutual trust and openness, while they offer exit-options at the same time; after all, the time span, the subject and the financial investments are limited and co-operation will stop, when the project is finished, or when research enters the competitive stage.

The network structure of the Dutch innovation system is dense and strongly interwoven. People know each other, often by first name and the open and informal attitude encourages informal contact. This system is strongly supported by Dutch openness towards technology and the willingness and ability to view problems from different sides. The Netherlands is on a cross-road of cultures and its strongest asset is to use this in a profitable way. The Dutch system of innovation does not has so many characteristics of its own, or it must be the capacity to adapt and adjust to the demands of the outside world.

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ANNEX I. T4. TELECOM FINLAND

From Foreign Domination to Global Strength: Transformation of the Finnish Telecommunications Industry

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Country-Sector Report as part of TSER-Project 'National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries'

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1. A brief history outlook

1.1 The duopolistic structure of the network operator market

The foundation for the Finnish telecommunications industry was laid during the 1880s. The Imperial Telephone Decree, which was enacted in 1886 when Finland was a Russian Grand Duchy, became the legal basis for the development of the sector. The decree authorised the Finnish Senate to grant licences for private sector local telephone operators (telcos), which explains why Finland's telecommunications operators are organised on a decentralised basis, as opposed to the public monopoly situation that has prevailed in most European countries (Palmberg 1999). The number of private operators started to grow very rapidly after the war and in the 1930s it was at its highest. Still, the harmonisation of the networks remained a technological challenge for equipment producers.

The state entered telecommunications operations in 1917 when Finland became independent. The Post and Telecommunications of Finland (PTT, since 1998 Sonera) was established in order to build trunk networks and local networks in certain scarcely populated areas. Through take-overs, the PTT gradually extended its position in the market. In 1921, the Association for Private Telephone Companies (the Finnet Group) was founded, not least to resist PTT's expansion (Paija and Ylä-Anttila 1996). Another major aim was to co-ordinate the activities of the telcos in certain administrative matters, and in matters related to procurement and the modernisation of the networks (Mäenpää and Luukkainen 1994). The group of private telcos and the state-owned PTT became the two competing actors in the Finnish telecommunications sector. The PTT gradually acquired the monopoly of international and long-distance calls and also for local calls in the remote areas of Northern and Eastern Finland to a small degree (Moisala et al. 1977). In addition, the PTT also had the role of the public regulator who controlled the technical standards and developed the legal basis for the operations of private associations and companies. The local telcos, on the other hand, maintained the network within the 'teledistricts' in which the operating licence gave a monopoly status to one company or association.

While the duopolistic structure retained the two camps from economic competition, some kind of technical running race emerged, also nurtured by an ideological competition as the two groups were linked with different political parties. Both camps tried to install the latest technology;

a situation, which guaranteed high technological standards of the telecommunication networks (Mäenpää and Luukkainen 1994, Paija and Ylä-Anttila 1996). In order to complete the network infrastructure and to manage the inevitable modernisation of the systems, both operator groups aimed at organisational and geographical centralisation. The end result was that the number of private local telcos decreased rapidly.

1.2 The evolution of Nokia in the telecommunications equipment sector

At the beginning of the 1960s, the Finnish telecommunications equipment industry was insignificant. The industry was dominated by an oligopoly of foreign manufactures, consisting of CIT-Alcatel, Ericsson and Siemens. But from the 1960s onwards, the domestic telecommunications industry gradually emerged, and step by step Finnish firms took over growing shares of the market. The 'Finlandisation' of the domestic market was very much interrelated with the growth of Nokia and an associated network of sub-contractors and component producers (Palmberg 1999).

The fact that foreign companies dominated the rather small Finnish market was not favourable for the growth of a domestic equipment industry in the telecommunications sector. Moreover, the technology and know-how of the dominating Finnish forest industry had little in common with the technology and knowledge in the electronic industry. However, some domestic expertise in telecommunications did exist from the very beginning. For example, the defence sector had established an R&D unit to cater for its demands for electronics and telecommunications equipment as well as for maintenance and repair. This unit became part of the PTT's activities, and in 1992, adopted the name Televa (Palmberg 1999). In the private sector, Suomen Kaapelitehdas (established in 1912), Salora (established in 1928) and Valtion Sähköpaja were the dominant Finnish equipment producers. In addition, the isolation and smallness of the Finnish market and some restricting import regulations also created some space for the development of Finnish equipment producers (Lovio 1993).

Due to the openness of the equipment market in Finland, national firms could not benefit from a protected domestic market, as was the case in other European markets. This has forced Finnish companies to strengthen competitiveness in their domestic operations and later on also pushed them to seek growth in foreign markets. In addition, the practice of the national telecommunications operators in both the public and the private camp to acquire their technology from different foreign and domestic producers created a situation of innovation competition, as the operators always demanded the most advanced technology. Strong competition from foreign companies explains to a great extent the innovative orientation of Finnish firms in this sector.

In the beginning, the subsidiaries of foreign companies channelled new technology to Finland and this contributed to the extension of the national knowledge base. They can be seen as a springboard for the gradual growth of the domestic industry from the 1960s onwards. But gradually Finnish companies started to develop their own technology on the basis of increased R&D activities. Later, when mergers of foreign companies with Finnish companies took place, such as that of Nokia Data with ICL, also Finnish export started to grow and Finnish business people acquired new skills and competencies in marketing. However, besides strong competition, co-operation between foreign and domestic companies took place on a more informal basis to put pressure on the public authorities to upgrade and extend the telecommunications networks (Lovio 1993).

The emerging new digital paradigm marks a historical divide in the Finnish telecommunications sector, as much of the relevant knowledge accumulated in the 1960s became obsolete. It not only forced the old, established companies to renew their products and production processes but also opened up opportunities for new companies to enter the market. The early 1970s marked the start of the growth of Nokia in terms of both market shares and accumulation of competencies and other resources. By 1980, Nokia had already become the largest domestic firm in the electronics and telecommunications industry. Two developments took place at the same time: the concentration of the industry due to the rapid growth of Nokia and the polarisation of the market. The number of medium-sized companies decreased, they either grew into larger companies or merged with larger companies. The small companies either needed to find a niche in the market or they became sub-contractors. At the same time, foreign companies lost their dominant position in the Finnish market and became only minor players.

Nokia's history can be described as a process of take-overs of mainly domestic but also foreign telecommunications equipment firms, on the one hand, and the disengagement from a number of firms in maturing forestry, cable- and rubber-works industries on the other. In 1985, Nokia had no less than eleven business lines, where the sales of cable and rubber still exceeded the sales of electronics. The process of disengagement took place together with Nokia's forceful diversification into electronics and particularly into telecommunications. Not least the process of de-investing provided Nokia with the financial resources to specialise in the telecommunications sector and to acquire the needed knowledge through mergers and take-overs. Since then Nokia has been transformed from an industrial supermarket to a focused telecommunications company (Ali-Yrkkö et al. 2000).

2. Technological developments in the digital paradigm

Drawing clear boundaries between the old electro-mechanical and the new digital paradigm in telecommunications is difficult as the main technologies in the new paradigm have been developed during the 1960s and 1970s, while the diffusion of these technologies has only started in the 1980s. According to Kaiser and Grande, the major technological trends in telecommunications "since the 1980s have been the digitalisation of the public telephone network, the optimisation of optical transmission technologies as well as the development of digital mobile communication systems and of high capacity access technologies for the local loop designed to handle the increasing demand in data communications" (2000: 38). Finnish companies had a major role in the development of the new technological paradigm; several new technologies were developed and first introduced in Finland.

The digitalisation of the public telephone network represents a significant innovation since it made possible the establishment of the ISDN network which integrates transmission of voice, data, text and images. The Finnish PTT started to build the ISDN network in 1987 and continued to invest heavily in the network in the early 1990s. In 1994, the pilot services of the ATM network were introduced in Finland. The PTT installed the first ATM network in the world in co-operation with the Tampere University of Technology (TUT) and Funet, a network of Finnish universities.

The advantage of optical cables is that they increase the speed of data transfer considerably. The Finnish PTT began to experiment with optical cables in the late 1970s. Today only some remote municipalities and a small number of rural villages in the country are not connected by optical cables.

The Finnish history of commercial mobile communication started in 1971 with the introduction of the Auto Radio Telephone (ARP) network. During the 1980s, two Nordic Mobile Telephone (NMT) networks using different frequencies were constructed (NMT 450 and NMT 900).

The development of the Global Systems of Mobile Communications (GSM) network started in 1987, when Nokia begun to co-operate with Alcatel and AEG in the ECR-900 consortium. In 1993, all urban areas and main roads were included in the GSM reception area. In 1995, service supply expanded with GSM Data and GSM Fax services.

The first GSM network, the GSM 900 was built to utilise the infrastructure of the NMT 900. Later, in the mid-1990s, when higher frequencies for mobile communications became available, the Finnish Government issued approval for the establishment and operation of new GSM 1800 (DCS) networks. There are now two GSM 900 and four GSM 1800 networks in operation in Finland. Since the establishment of the GSM mobile communications networks in Finland, the number of subscribers has increased dramatically. Originally, the GSM standard did not foresee the increasing demand for mobile data communications and it was not designed for mobile Internet access. However, the data transmission capacity of GSM networks can be increased significantly by technologies such as the General Packet Radio Service (GPRS) offered by Nokia. This technology connects the mobile telephone to the Internet.

The Universal Mobile Telecommunications System (UMTS) is expected to start in Finland in 2002. Its data transmission rate is 10–40 times higher than that of the GSM. Finland has granted the UMTS licences free of charge, based on the evaluation of the technical and economic competence of the applicants. The licences were granted to Sonera, Oy Radiolinja AB, Suomen 3G, Telia Mobile AB, a Finnish subsidiary of a Swedish company. The licences are nationwide and they are valid for 20 years.

3 The economic relevance of the Finnish telecommunications sector

During the past decade, the telecommunications industry has grown very rapidly and become more and more significant for the Finnish economy. The industry has generated a turnover of EURO 17.5 billion in 1998. Two thirds of the value-added are produced by equipment manufacturers. In 1998, the share of the telecommunications industry of GDP was 6.6 percent. About 85 percent of the total equipment manufacturing were exported in 1998; this was about 20 percent of the total Finnish export. About a decade ago, this share was only 5 percent During the 1990s, Finland became the most specialised country in telecommunications equipment among the OECD countries; the share of this industry of total export is greater in Finland than in all other OECD countries.

The Finnish telecommunications market amounted to about 1.5 percent of the total EU market in 1997. Finland's share is the largest with regards to the wireless terminal devices (2.9%). The Finnish telecommunications equipment market amounts to 1.8 percent and its telecommunications services market to about 1.4 percent of the corresponding EU market.

In 1997, information technology spending as a proportion of GDP in Finland was 2.6 percent, far from the numbers recorded in the USA (4.5%) and in Sweden (3.5%). The spending is about European average, but it is the lowest figure in the Nordic countries. Information technology expenditures per capita in Finland were below the figures of all other Nordic countries (EURO 520/person), with Denmark in the leading position (EURO 803/person). Among the countries participating in the research project, Finland ranks second behind the Netherlands, with respect to both figures.

In 1998, about 56 percent of all Finns had a traditional telephone. Already in December 1998, the number of mobile phones exceeded the number of ordinary, wired phone extensions, which is a very rare situation in OECD countries. In the same year, Finland became the first country in which over half of the population had a mobile phone. It is self-evident that Finland has taken the leading position concerning the diffusion of mobile phones among the countries participating in the research project. According to Network Wizards, there were about 500,000 Internet connections in Finland at the beginning of 1999; that is, 107 per 1,000 inhabitants, the highest figure in the world.[1]

In 1980, the telecommunications sector employed about 20,000 people, but in 1997 the number had already increased up to more than 37,000 people. Still, the sectors' employment in 1997 was only 1.7 percent of the total workforce in Finland. Employment developed differently in the two sectors. It dropped in the sector of telephone operators from its peak in 1990 to about 13,000 workers in 1997, resulting mainly from rationalisation processes in the privatised PTT. However, this development was more than compensated by the rapid growth of employment in the equipment industry.

Nokia has become so large that it not only dominates the Finnish telecommunications sector and the ICT industry but it also has a significant effect on the Finnish economy as a whole (Ali-Yrkkö et al. 2000). For example, Nokia accounted for slightly more than 3 percent of the Finnish

[1] These figures should be approached with caution, however, as they contain random counting errors.

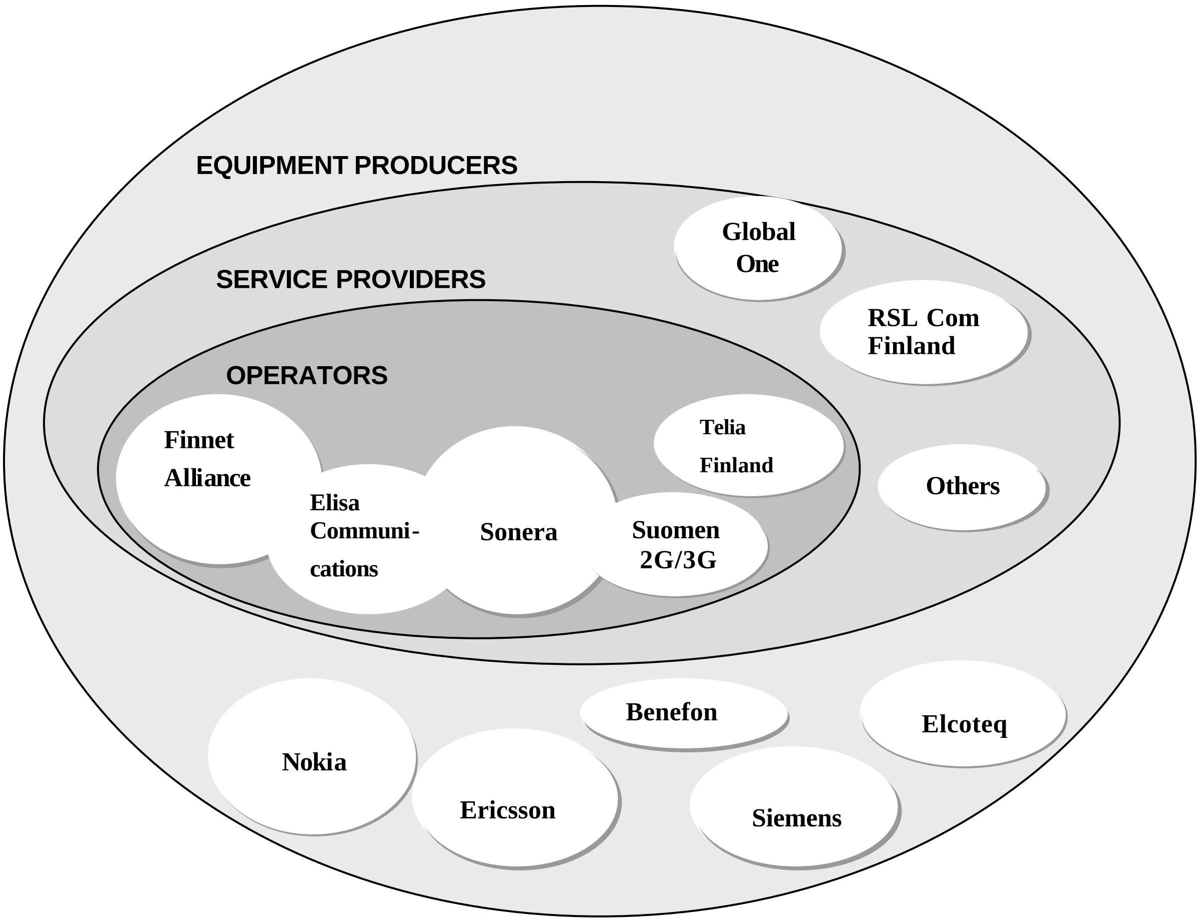
GDP[2] and 20 percent of total Finnish exports in 1999[3], while its value-added increased at an average rate of approximately 30 percent. The company's contribution to GDP growth was as much as one percentage point, which is higher than the contribution of the entire Finnish electro-technical industry. Furthermore, the company accounted for about one third of all R&D expenditures carried out by private enterprises in Finland, which is about 20 percent of the total R&D expenditures in the country.[4]

4. The emerging new structures in the Finnish telecommunications industry

Together with the transition from the electro-mechanic to the digital paradigm, a strong Finnish telecommunications industry has emerged. The industry is highly dynamic; major changes have taken place particularly in the field of the network operators during the past few years. The stronghold of the Finnish telecommunications industry is, however, equipment production; here a network of supplier and subcontractor firms has formed around Nokia, one of the world's leading companies in mobile telephony. Contrary to the internationalisation process in equipment production, network operators have remained rather national. Sonera's attempt to develop into a technologically sophisticated service company specialising in telecommunications and data exchange with products that are international brands seem to have failed. The other network providers are more nationally or even regionally oriented with some connections to the Baltic countries. The Finnish digital content industry is still in its early stage of evolution (Ali-Yrkkö 2001). Overall there is little involvement of foreign companies, although Siemens and Ericsson have kept a share of their earlier dominant position in equipment industry. Figure 1 gives an overview of the main companies in the telecommunications industry.

[2] Here also the subcontracting activities were taken into account (Ali-Yrkkö et al. 2000)
[3] Including goods and services (Ali-Yrkkö et al. 2000)
[4] The calculation is based on Nokia's Finnish personnel and a correction coefficient (Ali-Yrkkö et al. 2000: 12). It does not include subcontracting activities.

Figure 1: Key companies in the Finnish telecommunications industry



Source: Finnet Focus

4.1 Equipment production in the telecommunications industry

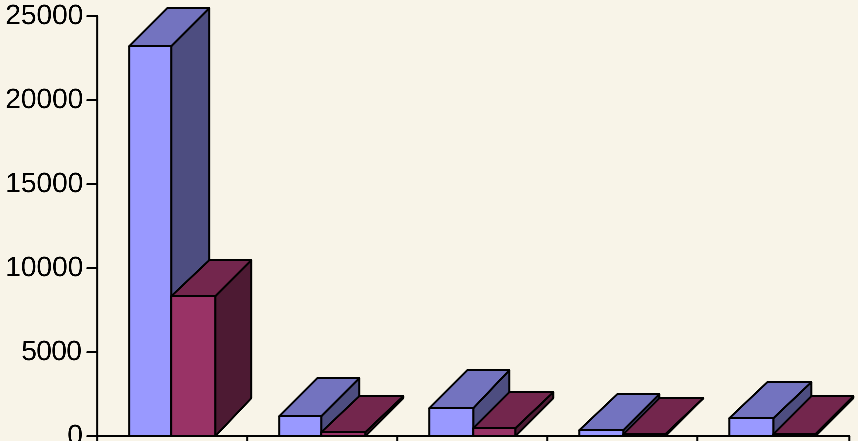
4.1.1 The dominant position of Nokia

As mentioned earlier, equipment producers form the core of the Finnish telecommunications industry. And here Nokia is by far the dominant company. Together with an increasing focus on its core competencies, the company has gone through major organisational transformation processes. An increasing number of functions have been outsourced and the company developed into an organisation with a large network of suppliers and subcontractors. The rapid global expansion of the core company had a bearing on the operations of its suppliers; they have started or increased their international operations including foreign trade and production abroad (Ali-Yrkkö 2001: 66). Nokia's tendency to work with global suppliers has turned the national network into a global one. Companies such as Benefon, a developer and manufacturer of innovative wireless communication devices, or Elcoteq, the biggest contract manufacturer of electronics in Europe, have very rapidly extended their international operations.

Although foreign equipment producers that have dominated the Finnish market in the electro-mechanical paradigm have lost ground since, Siemens and Ericsson still remain relevant actors in the idea-innovation networks of the Finnish telecommunications sector. Siemens' innovation strategy is based on the idea that R&D should be concentrated in the region or country where technology in a certain field is most developed. Therefore, Siemens has placed its Internet-business headquarters in Boston, and its Mobile Internet Solutions Unit in Finland. The reason to establish the latter unit in Finland is the belief that in this country mobile Internet solutions are an essential part of everyday life unlike in Germany, where the national culture is less technology-oriented.

There are some signs that the Finnish telecommunications market may even attract more foreign investment in the near future due to its high innovativeness and international competitiveness. Because of very sophisticated customers, Finland provides an excellent test market for new products. Figure 2 gives an overview of the economic position of the most important equipment producers in the Finnish telecommunications industry.

Figure 2: Employment and turnover of leading IT equipment producers in Finland in 1999



	Nokia	Ericsson	Siemens	Benefon	Elcoteq
Employees in Finland	23263	1200	1700	296	1023
Turnover in Finland (M€)	8304	192	404	39	148

From Nokia's perspective, the 1990s can be characterised as a decade of specialisation, rapid growth and internationalisation, although the company ran into an economic crisis at the beginning of the 1990s. But further divesting from maturing industries and full concentration on telecommunications brought Nokia back to a rapid growth path. From the mid-1990s until the end of the decade, the company grew by more than 30 percent per year. The immense growth rates are linked with a rapid global expansion with respect to both sales and production. Europe is still Nokia's biggest market area with little over 50 percent of the net sales in 1999, but the share of its net sales to the Americas (25%) and to the Asia-Pacific area (22%) has increased significantly. About half of Nokia's current net sales is produced abroad. Recently its foreign employment has surpassed its domestic employment. The fact that Nokia's production is more and more taking place outside Finland is motivated by the company's aim of reducing costs and getting closer to the international markets in order to better serve the diversified demand.

4.1.2 Organisational structures

Nokia is now divided into two business groups: Nokia Mobile Phones and Nokia Networks. Nokia Networks accounted for 33 percent of the net sales of the whole company in 1998 while Nokia Mobile Phones had 60 percent of the net sales. In addition to the two business groups, this Finnish telecommunications company includes the Nokia Venture Organisation and the Nokia Research Centre.

Nokia Mobile Phones is the world's largest mobile phone manufacturer with a market share close to 40 percent. This business group has a comprehensive product portfolio, which covers all major standards and consumer segments. Particularly advanced branding has helped Nokia to become the leading mobile phone manufacturer.[5] Nokia has also started to develop distinct designs for different customer groups. Nokia Networks develops and manufactures a broad range of advanced infrastructure solutions for a variety of customers including fixed operators, mobile operators, and Internet service providers. In addition, Nokia provides related network management solutions, customer services, and system integration. It is the world-leading supplier in GSM infrastructure, including wireless data solutions and also a significant supplier of broadband and IP network solutions. Recently finance has become an important competitive advantage in selling networks.

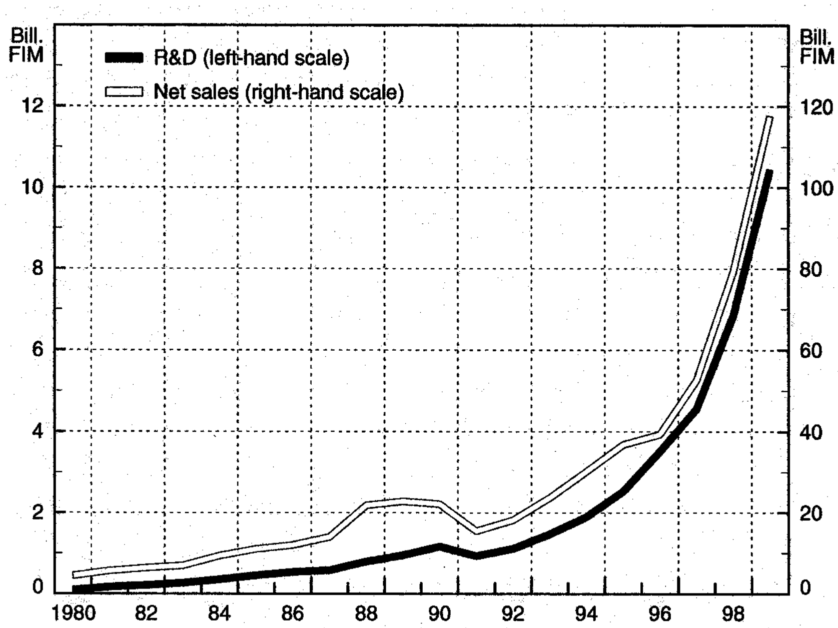
Nokia has adapted to the fact that flexibility and time in decision-making have become the key competition criteria by turning itself into a flat and project-based organisation. Establishing cross-functional design teams is a common practice in the company. Co-operation is supported by a strong and distinctive corporate culture based on Nordic egalitarism and reliability. Furthermore, the company invests heavily in further training to keep its workers up-to-date, as knowledge in the telecommunications sector becomes outdated rapidly. Nokia also tries to make use of the knowledge developed at the workplace through 'learning by doing'. Picking of new ideas is organised through the Internet. Anyone of Nokia's 55,000 employees can send their ideas to the mailbox on the Internet. But Nokia also aims at further improving its competitiveness by increasing productivity. The company is already planning its next leap in productivity; its entire operations will be turned into e-business by the year 2003 (Säntti 2001).

4.1.3 Nokia's R&D investment

[5] In a ranking of companies according to their brand value, conducted by an American company called Interbrand, Nokia has been ranked fifth as the

During the past decade, Nokia has continuously increased its R&D investment, following closely the growth rates of sales. Particularly in the past few years, growth rates in its R&D investment have accelerated together with rapidly increasing sales; from 1997 to 1999, Nokia's R&D investments about doubled. In 1998, Nokia invested about EURm 160, which means that 8.6 percent of its net sales were used within R&D in this year(see Figure 3). But Nokia's R&D expenditures amount to only half as much as those of its main competitors, Ericsson (19.0) and Motorola (19.2%). At the same time, the company's R&D personnel also grew very rapidly from 10,000 to 17,000 employees; roughly speaking, 30 percent of Nokia's entire personnel currently work in R&D. Particularly the development of new models and technologies for third-generation mobile phone systems has required additional investments in R&D. This seems to indicate that applied research and development work has become more important than basic research in recent years.

Figure 3: R&D and net sales of Nokia (FIM billion)



Source: Ali-Yrkkö 2001

Together with the rapid expansion of its R&D personnel, Nokia has created a global network of R&D centres; in 1998, it established 44 R&D centres in 12 countries, including Australia, China,

first non-American company.

Germany, Sweden, UK, and the USA. These international centres concentrate on development work, since one of their aims is to adapt products to different tastes and demands.

A major part of applied research and development is done in the two Business Groups. Research in the Nokia Research Center is closer to basic research, as longer-term research perspectives are predominant. Researchers from the Research Center often co-operate with those from technical universities and other research institutes in joint projects. In addition, Nokia engages in strategic R&D partnerships with both large leading companies in the telecommunications business but also with small high-tech firms. Monitoring technological development very closely is another strategy of acquiring new knowledge. For example, Nokia is a partner in most Finnish Centers of Expertise, which allows the company to monitor closely new technological developments in small Finnish high-tech firms.

4.1.4 New business perspectives

The establishment of the Nokia Ventures Organisation, located in Silicon Valley, is a very recent development. The aim of the new unit founded in 1999 is to ensure a systemic way of expanding also beyond the natural growth track of the current core businesses, which means exploring new businesses alternatives outside the scope of Nokia's actual operations (Vihma 2001). Nokia Ventures Organisation is divided into two sub-units: Ventures Unit and Ventures Fund. The Ventures Unit is further divided into Nokia Internet Communications and Nokia Home Communications. The first product developed within Nokia Internets Communications is a fixed-line Internet security package, which will start selling this autumn. Also the Nokia Home Communications will start selling its first product, a Linux-based Media Terminal, this autumn (Holtari 2001).

Now that it is approaching the Internet World, Nokia is applying the 'open-source development model' (Tuomi 2001). The basic idea of this model is that the users themselves create a complex technical system, forming a developer community. Developing the technical system takes place within an informal, self-organising social community. Recently, Nokia Home Communications has opened up the 'source code' of its products for outsiders to speed up the development of new services.

For the past few years, Nokia has been exploring the outside world by means of its venture capital fund, Nokia Venture Partners. It is equipped with EURm 650; it is also the world's biggest and only fund to invest exclusively in the wireless Internet. Its objective is to learn about new technologies, markets and business models. Nokia is the fund's biggest industrial partner but it is open for other partners as well.

4.1.5 The network

Nokia has changed its mode of co-operation with suppliers and subcontractors significantly during the past 15 years (Ali-Yrkkö 2001). In the beginning, co-operation was mostly traditional subcontracting with the aim of buffering business cycles and stabilising manufacturing. At the beginning of the 1990s, Nokia started to outsource its in-house manufacturing of accessories and to establish long-term partnerships with its subcontractors. In the mid-1990s, the company restructured its entire production chain, reducing the number of co-operation partners significantly by using assemblers and system suppliers. Nokia itself focused its efforts on such core competencies as research, software production, final product design and brand management (Tuisku 1999: 14). There is also a trend towards working with global suppliers not only from Finland but also from abroad. Nowadays the company procures all the components for the mobile phone system from suppliers in various parts of the world.

During the past few years, Nokia has extended its range of co-operation partners by using software and even R&D subcontractors. The next step in developing the network further will be to introduce risk and profit sharing. Subcontractors become responsible for the long-term development of their sub-systems, which means that they are expected to conduct their own R&D work in close co-operation with Nokia and to bear more financial risks. As Nokia is aiming at developing long-term partnerships, demands with respect to suppliers' and subcontractors' financial resources, skills of the workforce, research capacity and visionary orientation are very high (Ali-Yrkkö 2001).

Not only material flows, but increasingly also information flows, are the target of restructuring of inter-firm co-operation. Operational units communicate directly with each other supported by modern ICT without hierarchical mediation and interference. The formation of joint development teams with suppliers has become very common. Also, exchange of staff is a widespread practice; several managers of supplier firms have previously worked with Nokia. This results in the development of trust-based relationships, makes knowledge flows easier and prevents knowledge from getting stuck in the inter-firm network.

Most of Nokia's network partners are of the opinion that mutual benefits have been achieved (Ali Yrkkö 2001). Some supplier firms and subcontractors have grown very rapidly and developed into global companies. They have developed more efficient ICT-based organisation forms and employed more skilled people. Participating in the network has also widened the suppliers' customer basis.

4.1.6 Future challenges

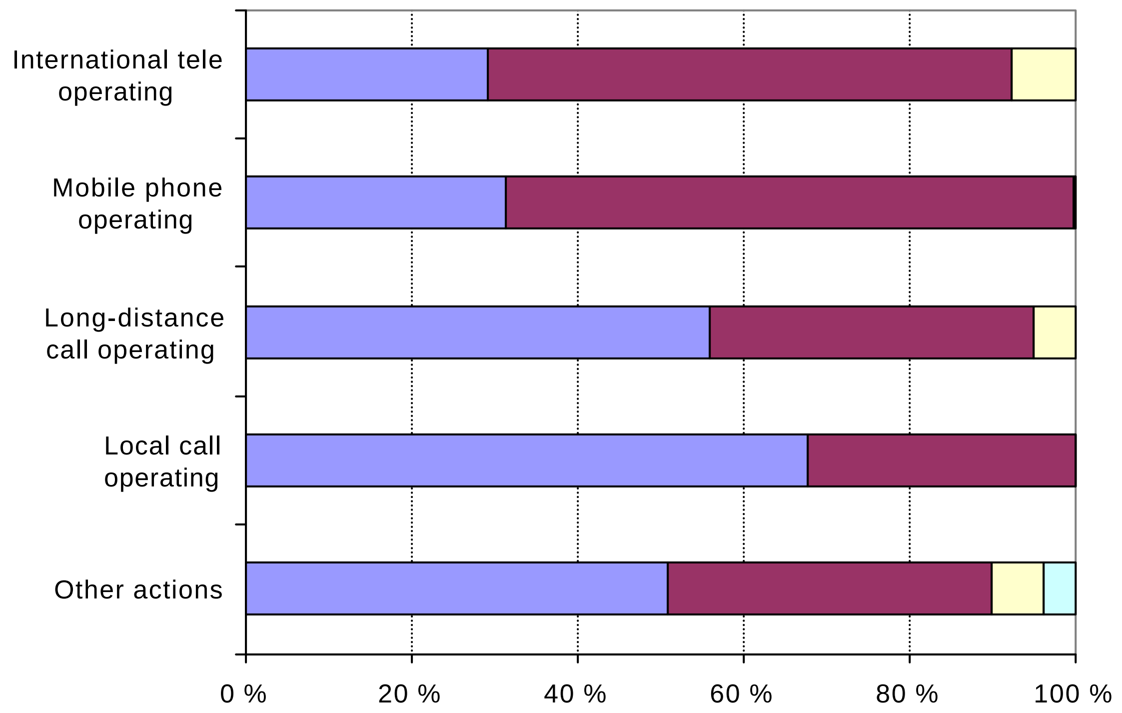
Nokia may face major problems in the near future. Sales of mobile phones have been sluggish lately due to the delay in the introduction of the third generation of mobile communications. In addition, the company faces increasing competition from Asian handset manufacturers entering the European market. As mobile phones and handheld computers are converging in the near future, Nokia may also compete with companies that have not previously been prominent in the mobile phone market; the main competitors will include manufacturers of personal digital assistants. And it is possible that equipment manufacturers, network operators, and service providers form new alliances. There will definitely be more competitors in the market than there are nowadays.

Furthermore, as network operators had to spend enormous sums of money to secure UMTS licences, equipment producers are pressured to finance bigger parts of the formers' investments. The Internet business seems to be very promising; however, this is a new business sector for Nokia, in which the company has to compete with large old-established firms.

4.2 The network operators: Sonera – unfulfilled hopes

After the liberalisation and together with the emerging digital paradigm the actor-constellation among the network operators in Finland has changed significantly. Most importantly, the two camps, the national PTT and the association of regional operators, have both lost their monopolistic position on the national respectively local level. There is now full competition in all areas, local networks, fixed national networks and mobile networks, data transmission and service provision. In addition, the shrinking process among local network providers has continued, while at the same time new companies have emerged out of split-off processes. By the beginning of 2001, two of the most notable regional telephone associations, Elisa Communications (former Helsinki Telephone Association) and Soon Communications (former Tampere Telephone Plc.) had left the Finnet Association. After having separated from the Finnet Group in 2000, Elisa Communications became the largest privately owned provider of local, national and international telecommunication services in Finland. Figure 4 gives an overview of the position of the key network operators.

Figure 4. Distribution of turnover among network operators in Finland in 1998 (FIM million)



	Other actions	Local call operating	Long-distance call operating	Mobile phone operating	International tele operating
Others	254				
Telia Finland	420	1	20	10	91
Sonera	2638	1340	157	4750	763
Finnet	3429	2820	226	2170	355

Source: Telecommunications Statistics of Finland 1999, 65

In 1990, the privatisation process of the national PTT started. It was first transformed from a state-owned monopoly into a state-controlled enterprise (named Telecom), and its operations were detached from the state budget. It was bound by the same rules as the regional telcos. In 1997, the Parliament approved a partial privatisation of Telecom Finland and authorised the Council of State to sell 49 percent of the shares of the company. The company, later on named Sonera, is listed on Helsinki Stock Exchange and also on the Nasdaq. Sonera is now the leading network operator in Finland. The company employs about 9,000 people; most of them work in Finland.

The company had the vision to develop into a technologically sophisticated service company specialising in telecommunications and data exchange, with international brand products. The aim was to become more than a traditional network operator; instead, Sonera should be compared with content producers and portals, technology wizards and application dealers (Säntti 2001). To develop new value-added services, Sonera invests about 3 percent of its revenues in R&D.

A major problem for the company is that the UMTS technology is slowly coming of age and that the market is maturing even more slowly. It is very likely that in the future there will be great demand for innovative services, but so far simple short messaging leads the field for value-adding services. And although Sonera is competing in a market which still has growth potential, there is an escalating competition: not only are network operators in the middle of harsh competition, but also equipment producers, software houses and media companies may enter the scene.

In addition, Sonera aimed at becoming a globally oriented network operator. In 2000, only 5 percent of the Sonera Group's net sales were generated outside Finland. Therefore, the Group has built up its international operations very rapidly. In 2000, Sonera had subsidiaries and associations in 14 countries (e.g. in Turkey, the US, and the Baltic countries). But more importantly, the company has actively participated in the international competition of acquiring UMTS licences. It has received UMTS licences from five countries: Finland, Norway, Italy, Spain, and Germany. Outside Finland, the licences have been acquired as a partner of various consortia. But acquiring the licence for Germany in particular has led to huge debts, which the company has increasing difficulties to handle.

In order to be able to play a major role in the global market, the company needs support from one of the bigger players in the field. The Finnish Parliament has paved the way for a merger or take-over by allowing the Council of State to further reduce the state's part of the shares. Talks have taken place with several potential partners but no agreement has been reached yet. Without the support of a strong partner, Sonera will hardly be able to continue its very ambitious strategy.

4.3. University-industry co-operation

4.3.1 Towards an interactive mode of university-industry co-operation

Co-operation between telecommunications companies and universities in Finland is very intensive. While the most significant networks in the development of telecommunications technology are the procurer/user-producer interactions and vertical and horizontal co-operation among the various telecommunications firms, the networks also cover collaboration with several research teams at the technical universities and the Technical Research Centre of Finland (VTT) (Palmberg 1999). For example, during the development of competencies anticipating the pan-European GSM standard, collaborative knowledge creation involving universities, VTT and the companies has been very crucial (Lemola 1996).

A more recent trend seems to indicate that the distinction between different types of research and knowledge creation are becoming blurred. The traditional knowledge-transfer model, which assumes a linear transfer of knowledge from universities to industries, has lost its relevance, we can nowadays speak about a 'collaborative' or an 'interactive mode of knowledge creation'. The traditional motive of companies to set up contracts with research laboratories was to purchase knowledge produced by the latter. Companies have developed their research capacity to be able to absorb basic scientific knowledge. The new form of contracts can be seen more as a subsidy of the firm to the laboratory, which gives firms the right of access to the laboratory's networks rather than an agreement on the delivery of specific services (Cohendet 2001). Companies' aim of developing their research capacity is now that of stimulating a process of joint creation of more fundamental knowledge, which is less directly applicable by other firms. A main aspect of the new relationships between research laboratories and industry is the exchange of tacit forms of knowledge.

The latest emphasis on competitive funding, which to a great extent is channelled through *Tekes*[6], also supports university-industry co-operation in Finland. In addition, *Tekes* and the Academy of Finland have started to launch joint research programmes, which can be seen as reflecting the blurring boundaries between applied and basic research.

[6] The National Technology Agency is the main financing organization for applied and industrial R&D in Finland. For

4.3.2 Universities of technology and the Technical Research Centre of Finland (VTT)

All three main agglomerations of the Finnish telecommunications industry are build around a university of technology. This spatial proximity indicates the central position of universities in the idea-innovation-networks of the telecommunications sector and the importance of university-industry relations. Universities are understood as a driving force for developing regional agglomerations of telecommunications companies.

Helsinki University of Technology (HUT) is the oldest and largest university of technology in Finland. It has two departments that are involved in basic research in the field of telecommunications. They are the Department of Computer Science and Engineering and the Department of Electrical and Communications Engineering. The Department of Computer Science and Engineering has four laboratories and research centres. The Laboratory of Information Processing Science focuses on the field of software engineering, including data base management and digital media technology. The Laboratory for Theoretical Computer Science is conducting research in areas such as coding theory and theory of knowledge representation and reasoning. The Telecommunications Software and Multimedia Laboratory has research groups focusing on virtual research environments and on the architecture for broadband networks. The Laboratory of Computer and Information Science together with the Neural Networks Research Centre has become a Centre of Excellence in research selected by the Academy of Finland.[7] The Department of Electrical and Communication Engineering has altogether 20 laboratories that are often closely linked to the telecommunications industry. For example, in the Communications Laboratory, research is focused on radio systems and networks, multimedia services and optical fibre communications. In the Laboratory of Telecommunications Technology, research concentrates on basic telecommunications traffic.

Recently the HUT and the University of Helsinki have founded a common research institute, the Helsinki Institute of Information Technology (HIIT). One of the main areas of research will be mobile data processing based on portable terminals. The HUT has also founded a specific unit, the Otaniemi International Innovation Centre, to provide a qualified research liaison as well as to

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more details, see page 26.

[7] The aim of the Centres of Excellence Programme in research is to raise the quality of scientific research in Finland, to bring basic research and applied research together and to produce new innovations that in the long run will have significant commercial and social applications (Academy of Finland 2000).

contract innovation services for the university. The search for and evaluation of innovations is one of the most significant tasks of the centre; protection, management and marketing of innovations developed in the HUT institutes and laboratories is another important task.

The Tampere University of Technology (TUT) is also placed in an agglomeration of telecommunications companies, including Nokia, which has a large research centre in this agglomeration. Two of the departments at the TUT focus on research areas connected to telecommunication: Automation and Automatic Control Engineering and Digital and Computer Technology. The Digital Media Institute is a separate unit, positioned directly under the presidency of the TUT.

The agglomeration of high-tech companies in Oulu is often compared with 'Silicon Valley'. The University of Oulu, and its Faculty of Technology in particular, is an important actor in the regional innovation system of the Oulu area. Infotech Oulu is a research centre, which was founded in 1996. The aim of the centre is to promote long-term research in information and telecommunications technology. The centre consists of various research groups, nine of which are selected by external evaluation. Some groups are jointly formed by researchers from the University of Oulu and the Technical Research Centre of Finland (VTT). With a staff of more than 400 researchers, Infotech Oulu has become one of the leading telecommunications research centres in Finland. Research activities of Infotech Oulu take place in the following four main areas: electronics and measurement technology, information processing, software engineering, and wireless communication.

The governmental Technical Research Centre of Finland (VTT) is the largest expert organisation in Finland that carries out technical and techno-economic research and development. The aim of the R&D efforts at VTT is to improve the technological competitiveness of the Finnish industry, to foster the creation of new business based on new technical innovations, and to promote employment and production. Product development is a core activity of VTT. Technology and research programmes play a major role in VTT's strategic research; most of them funded by *Tekes* or by the Academy of Finland. The involvement in *Tekes*' 'Technology Clinic Programme' is a major activity of VTT. The purpose of these clinics is to make the knowledge and know-how accumulated in research institutes and universities more readily accessible to SMEs.

Out of the nine research institutes at VTT, three carry out research in the field of information technology: VTT Electronics, VTT Information Technology and VTT Automation. The rapid growth of electronics and information technology industries has led to increasing orders from the respective industries. All three institutes are increasingly involved in international research projects and they participate in several EU programmes.

The core expertise and research work of VTT Information Technology are divided into four groups: Information Systems, Telecommunications, Service Networks, and Media. The Information Systems Group concentrates on developing methods, software and information systems for handling large volumes of data. The Telecommunications Unit focuses on developing switching and implementation technologies, radio and microwave technologies, antennas, wireless system planning, and simulation tools. The main focus of the Network Group is to develop environments required by Internet applications and service platforms. And the Media Unit develops technologies, software and value-added services for electronic communications. A new research area, Human Interaction Technologies, was established in 1999.

5. The changing institutional setting

The new technological paradigm has not only triggered major changes in the intra- and inter-organisational governance of telecommunications companies; it has also led to changes in the institutional environment. Perez (1983) has pointed out that fundamental technological novelties can only become transformative together with major institutional changes. It is likely that the social and institutional framework, which is hospitable to one set of technologies, will not be suitable for a radically new technology. Whereas incremental innovations can be easily accommodated, this may not be the case with radical innovations, which by definition involve an element of creative destruction.

The development of a strong telecommunications sector in Finland has often been characterised as a national project. There is no doubt that the Finnish telecommunications sector represents a good example for an industry that has gained global competitiveness through companies' specialisation and restructuring processes, but major institutional changes have very much supported the change process. Here we discuss the following institutions: regulation and standardisation, public technology and innovation policy, as well as finance and education.

5.1 Regulation and standardisation

5.1.1 The regulation function

In addition to the fundamental changes in the technological basis of the telecommunications industry, the regulatory framework has changed significantly since the mid-1980s. Liberalisation of the domestic regulatory regime has started relatively early in Finland; the country can be seen as a pioneer in the liberalisation process. Deregulation of the telecommunications industry is part of Finland's efforts to foster competition and to dismantle monopolies in the entire economy. Of course, the deregulation in England under Thatcher can be seen as some kind of model. However, while deregulation in England was a comprehensive socio-political change, the liberalisation process in Finland was much more pragmatic. It was a reaction to the possibilities related to the new technology and the demands of the market.

The Telecommunications Act of 1987 changed the regulatory system of telecommunications in Finland significantly. The Ministry of Transport and Communications received regulatory power over technical supervision and inspection of telecommunications services, allocation of radio-frequency and number planning, type approval, and national standards. Before, the PTT had a very ambiguous double role in the Finnish telecommunications industry in being both a powerful actor and the regulatory body in the business. The PTT in particular had full discretion in granting new licences to and exercise control over other competing operators. The new Telecommunications Act separated the two functions. A new executive body, the Telecommunications Administration Center, has been established under the responsible Ministry of Transportation and Communication. Within the ministry, the regulatory function and the economic function of being the owner of PTT's property were clearly separated. This organisational split favoured the development of an open discussion culture and the ministry used negotiations and discussion rounds as its basic tool to establish regulations.

In 1988, corporate telecommunications and data transmission were deregulated. Licences for long-distance and international calls have been granted not only to an affiliated company of the PTT but also to a company established by the association of the regional telcos ending the monopoly of the PTT in these markets. Within the field of mobile communications, the monopoly of the PTT ended in 1990, when not only PTT but also the regional telcos received a licence to operate the GSM network through the founding of a joint venture named Radiolinja Ltd. (Telecommunications Statistics 1989 and 1996).

Since 1987, several new licence applications have been approved. Normally all licences include the self-provision of networks. But in fixed and cellular network operations, only the association of the telcos and the PTT had been given unlimited licences. There are also a number of service providers without the right to provide their own network. Value-added network services never needed any kind of licence; switched data network services are under notification procedure (Paija and Ylä-Anttila 1996).

In 1996, an act describing the rights and obligations of service providers was passed; it entails the obligation that subscriber lines have to be leased to competitors. This guarantees new actors fair access conditions to the public network. All networks have full relevant interconnection obligations. The service operator charges an interconnection fee straight from the customer (Paija and Ylä-Anttila 1996).

In Finland, prices are set by the market, which implies that there is no obligation for network operators to serve everybody at the same price, not related to costs. Consequently, prices vary a lot in different parts of the country. On the other hand, each operator is obliged to serve all customers within its license area at a reasonable and cost-oriented price. Despite price differences, in general, all users have profited from full competition. Finland, for example, is among the countries with the lowest mobile telecommunications charges (Paija and Ylä-Anttila 1996).

5.1.2 Standardisation

In the beginning, the national PTT was responsible for the standardisation function. It laid down technical standards which the equipment producers had to meet to receive contracts. The PTT was equipped with the necessary laboratories to test the equipment produced by various companies. Cooperation with the Nordic countries started in 1969, when a working group was founded to identify the needs and main principles of a Nordic Mobile Standard. The group developed the NMT Standard 450, and later on, the NMT Standard 900. For Nokia, the development of the Nordic standard was very important, since during the procurement stage, the company developed its mobile switching system in accordance with the NMT Standard 900 in close co-operation with the national PTT.

On the European level, the Finnish PTT participated in the work of the International Telecommunications Union, which had set up a consulting committee (CCITT) to ensure inter-operability of communications infrastructures on an international scale. The implementation of the agreed standards by the national PTTs took place on a voluntary basis. By the end of the 1980s when the European Commission started to intensify its telecommunications policy, the standardisation of national communications infrastructures became an important issue. In 1988, the European Telecommunications Standards Institute (ETSI) was founded, in which the manufacturing industry soon became the dominant party.[8] Standards had to be developed more often, because the pace of technical change in the industry increased rapidly; this is why the traditional standard setting procedure became too slow. It became impossible for international standard organisations to follow the pace of technological development. Therefore, *de facto* technical standards are increasingly developed among a limited number of firms and this takes place more and more often outside the EU forum. After the industrial alliances have agreed upon a new standard, it is brought as a result to the public area and outsiders are urged to use the standards not to be left out of what can be seen as the technological forefront (Luukkonen 2000: 22).

The process of standardisation, we can conclude, has changed significantly. While the national PTTs previously played a dominant role in the standardisation process, nowadays the equipment producers have become the key players. Second, the processes of technology development and standard setting become more and more intertwined, which means that the pace of standard setting has increased. And finally, to allow global communication, national standards are replaced by international standards.

[8] The ETSI has an important role to play in the standardisation process, since there is a rule according to which all firms that own central patents relating to a standard are urged to give their patents to the pool. They receive a reasonable compensation if the standard is accepted but are prevented from exploiting their asset and charging too high a compensation. On the other hand, companies that do not own patents can buy the licence at reasonable costs (Luukkonen 2000: 23).

Technology and innovation policy

Only after the mid-1980s, when mobile telecommunications started to spread, the sector became a prioritised target in the Finnish technology and innovation policy. Initially the government authorities showed little commitment towards the development of this technology: there was no clearly articulated telecommunications policy. The aim of technology policy at that time was to increase R&D intensity but not to support structural changes in the first place. Demand-oriented policy, such as public technology procurement, on the other hand, was much less developed in Finland than in other countries (Palmberg 1998: 190).

5.1.3 The procurement policy of the PTT

However, technology procurement took also place in Finland but in a decentralised and not co-ordinated way. The state-owned PTT's technology procurement in the 1980s had played a decisive role in the development of the telecommunications industry and particularly in Nokia's successful transformation. Until 1987, the PTT had acted as a *de facto* policy-maker through its control over the process of granting radio frequences and licences (Palmberg 1998). And Nokia's close co-operation with the PTT, supported by the fact that Nokia had taken over parts of PTT's businesses during the 1970s and 1980s, is worth mentioning as an influencing factor.

The procurement policy of the PTT was not motivated by the principle of supporting the 'national champion' in the first place; instead, its aim was to support technological development to be able to provide high service quality. Another motive for supporting the development of the domestic production of digital switching systems was to avoid too tight a dependence on foreign companies. Furthermore, the PTT has not only functioned as an important and competent user but even more important was its active role in the stimulation and formation of competence networks, including telecommunications companies and research institutes. The formation of such networks was supported by the fact that very close personal ties existed and that the mobility of staff was quite frequent in this industry.

Tekes and the National Technology Programmes

Together with the rapidly growing electronics industries and particularly telecommunications during the 1980s, public funding also shifted to these areas. Information technology was recognised as offering new growth opportunities and a possibility to reduce the dependence on the dominating forest industry (Lemola and Lovio 1998). The national technology programmes launched and co-ordinated by the then newly founded Technology Development Centre (*Tekes,* later the National Technology Agency) in the beginning had a strong focus on electronics and mobile phone technology.

From the start, *Tekes* applied a strong network approach in all its programmes. It supports different types of networks: co-operation among R&D institutes, pre-competitive horizontal co-operation among companies, as well as vertical co-operation and networks of SMEs with larger companies and with R&D institutes, aiming at covering the whole value chain from R&D to marketing. Several inter-organisational research teams have been created, for example during the development of competencies, anticipating the European GSM standard (Lemola 1996). *Tekes*' networks approach is build on the following principles (Schienstock and Hämäläinen 2001):

- applying a holistic perspective, which means that companies are evaluated as a whole to identify all possible weaknesses;
- supporting international co-operation with research institutes outside Europe, particularly in the USA and in Japan;
- improving the contribution of Finnish companies and research institutes to the international innovation networks by acquiring the co-ordinator function;
- adding complementary organisational and management knowledge and competencies; and
- continuous renewal of the networks through the integration of new partners.

As early as the late 1980s, information technology lost its dominant position in the national technology programmes. In 1982, the share of information technology was 62 percent, in 1985, it was 51 percent, and in 1991, only 29 percent of technology programme funding. The reason was that giving priority to telecommunications in technology policy did not take place unchallenged. The declining finance of information technology and telecommunications was due to the fact that technology policy became the object of criticism in the late 1980s. It was argued that excessive resources were given to the area of advanced technology, while emphasis should have been shifted towards safeguarding the competitiveness of basic industries in Finland and to the application of technology in traditional fields of knowledge. This dispute may have delayed, although not prevented, the transformation process towards a dominant position of telecommunications in the Finnish industry (Lemola 1996). Telecommunications could manage to grow very rapidly, even with declining public support because the industry was less dependent on public R&D funding as it increased its own R&D funding significantly.

5.1.4 The national innovation system approach and the 'knowledge society' as systemic vision

A new phase of the Finnish technology policy started at the beginning of the 1990s,. The 'knowledge society' became the 'systemic vision' of development, which gave the technology policy a new orientation (Schienstock and Hämäläinen 2001). At the same time, policy-makers focused on the development of the 'national innovation system' in which knowledge-based industries played an important part. Particular attention was given to the telecommunications industry and more broadly to the competitiveness of the infrastructure necessary for the application of information technology and for the knowledge-based society (Lemola 1999). The establishment of an efficient research and education infrastructure was given high priority.

In 1996, the Cabinet Economic Policy Committee decided to gradually increase public R&D expenditures for the following two years. In 1998, public funding totalled more than 3 percent of the Government budget (Statistics Finland 1999); a major part of public R&D funding has been reserved for the newly introduced 'cluster programme' (Pentikäinen 2000). One of the eight cluster programmes was established in the telecommunications industries, co-ordinated by the Ministry of Transportation and Communications. Improving co-operation among cluster members, increased knowledge flows and spill-overs, networking, and deepening co-operation within and between the public and private sectors can be seen as most important preconditions for reaching the aims of the cluster programmes. These are generating growth, improving industries' competitiveness and productivity, increasing employment, generating innovation, and improving social welfare

(Pentikäinen 2000: 9 – 10). Only marginal funds were given to R&D projects; it was assumed that cluster members would seek other public and private funding (Science and Technology Council of Finland 1996).

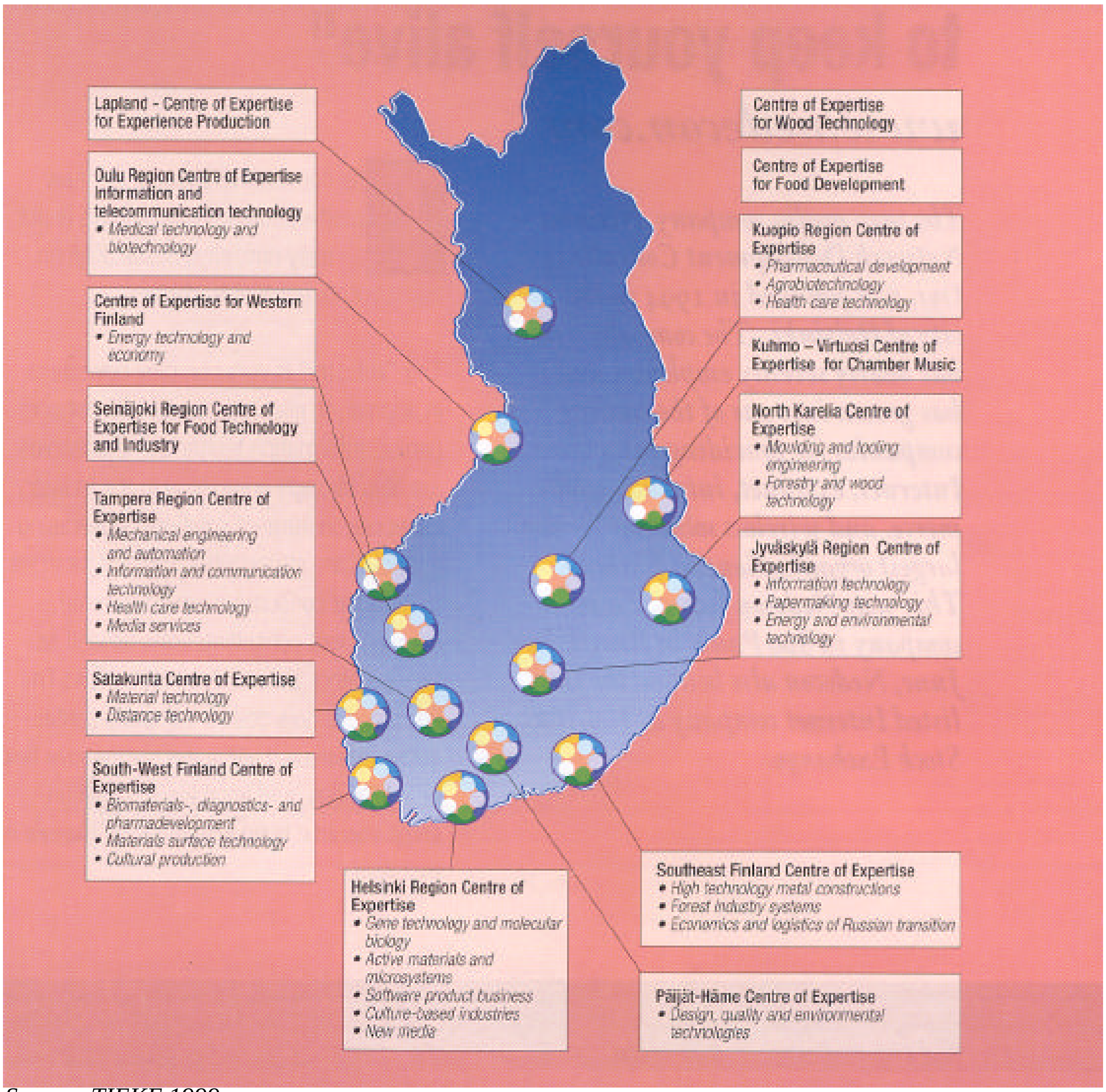
5.1.5 The regional dimension and European co-operation

The regional dimension of technology and innovation policy in Finland was invisible until the mid-1990s, when a National Centres of Expertise Programme was launched by the Ministry of the Interior. The basic idea of the programme is to enhance and further develop high-level know-how in regional economies instead of supporting their weak technology areas. In the long run, the programme should lead to the development of specialised regional agglomeration economies, including a number of globally acting high-tech companies, highly specialised supplier firms, local pools of labour with complementary skills and competencies, a cultural and institutional infrastructure, and the development of trust relationships among key actors. Stimulating inter-firm co-operation and network formation with support institutions is seen as an important tool to reach the aspired goals.[9]

Currently the programme includes 16 Centres of Expertise; among them there are six Centres of Expertise which explicitly specialise in the field of telecommunications: Technology Centre Kareltek Inc. (Lappeenranta); Otaniemi Science Park LTD (Espoo), Tampere Technology Centre LTD Hermia, Technopolis Oulu Plc., Culminatum LTD (Espoo), and PrizzTech LTD (Pori) (see Figure 5). However, almost all centres have information technology, electronics, or media services as a field of expertise.

[9] The Centres of Expertise are selected through heavy competition. The quality of research and education, companies' competencies in the field, co-operation among firms and supportive institutions, international co-operation, impact on the regional and national economy, specialised know-how, networking activities, and financial commitments are the main criteria for selecting Centres of Expertise.

Figure 5: Centres of Expertise in Finland



Source: TIEKE 1999

Since Finland became a member state of the European Union in 1995, its participation in the EU research programme has increased significantly. Participation in the Fourth Framework Programme was almost four times higher than in the previous programmes. The telecommunications sector is one of the most active industrial sectors in participating in the three framework programmes of the European Commission. Information and telecommunications technology has received almost one third of all the EU money that has come to Finland. The breakdown of the funding received by Finland by functions and programme areas does not differ significantly from the overall breakdown of EU funding, except in the case of information and telecommunications programmes (Academy of Finland 2000). In Finland these two fields received a considerably larger proportion of the research funds than in the EU's framework programme in general. Of course, Nokia is the most active Finnish participant in the EU framework programmes, but particularly in the telecommunications sector, the share of SMEs participating in the programme is very large.

Table 1: Funding for the EU Fourth Framework Programme

Programme	**EU EURO million**	**%**	**Finland EURO million**	**%**
THEMATIC PROGRAMMES				
Information and Communications Technologies	3,668	27.8	68.5	32.9
Industrial Technologies	2,140	16.2	30.8	14.8
Environment	1,157	8.8	18.7	9.0
Life Sciences and Technologies	1,709	12.9	34.4	16.5
Energy	2,412	18.3	33.5	16.1
Transport	263	2.0	6.7	3.2
Targeted Socio-economic Research	147	1.1	2.5	1.2
HORIZONTAL PROGRAMMES				
International Co-operation	575	4.4	2.6	1.3
Dissemination and Optimisation of Results	352	2.7	3.8	1.8
Training and Mobility of Researchers	792	6.0	6.4	3.1
TOTAL	**13,215**	**100**	**207.9**	**100**

Source: Niskanen et al. 1998

One aim of Nokia's participation in the EU programme is to become internationally more visible, and another to be able to monitor technological development elsewhere. From Nokia's viewpoint, a major contribution of the EU collaboration is an enhancement of skills and competencies. As changes in the framework programme have enabled pilot applications and demonstration projects with customers, Nokia views its participation in EU programmes now as a possibility to build future markets (Luukkonen and Niskanen 1988).

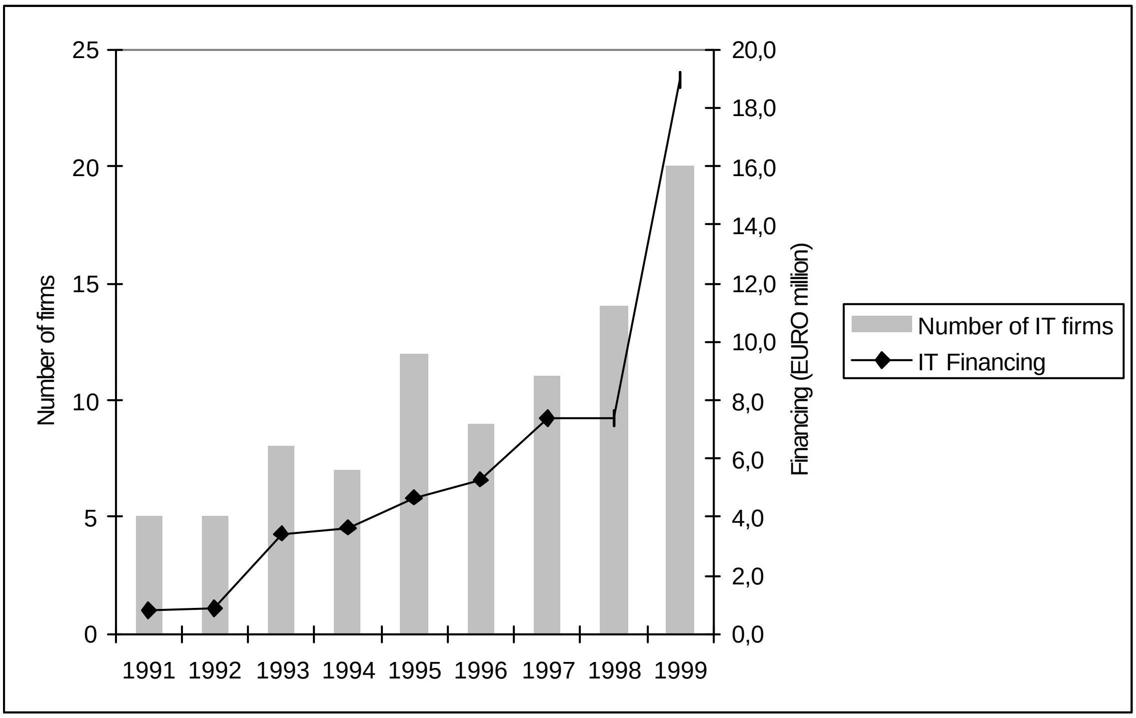
Finance

Financial resources allocated to R&D in Finland have increased 2.5-fold over the period 1985–1998. In the latter half of the 1990s, the growth rate was about 14 percent per year. In 1998, the total R&D expenditure amounted to about EURm 3,300, of which slightly less than one third was procured by the state (Kolu 1998: 37). One fifth was used in universities, two thirds in enterprises and the remaining share in public-sector research institutes. R&D expenditures in the information technology sector have increased even more rapidly. In 1997, the available R&D resources were five times higher than in 1985. In the other sectors, expenditures have grown by only one third in the same period. In 1997, about 45 percent of the total R&D expenditures in Finland were allocated to R&D in the field of electronics and telecommunications, which corresponds to an amount of EURm 850 (Statistics Finland 1999).

Public financing concentrates on the forepart of the idea-innovation chain, on basic and applied research and to a minor extent on product development. In 1998, the total finance of basic research in information and communication technologies was EURm 90, of which the share of public funding was 62 percent (EURm 55). The Academy of Finland, the main funding institution for basic research, increased its finance allocated to information-technology-related areas from EURm 11.2 in 1996 to EURm 16.1 in 1998 (Hattula 1998), which was distributed to universities. One can estimate that the additional financing of basic research in universities for the information technology sector was about EURm 35 in 1998 (Kolu 1998). About 51 percent of the research funding came from the state budget; the rest came from the Academy of Finland and from the private sector. Basic research is also located in research institutes, such as the publicly financed Technical Research Centre of Finland, VTT.

Tekes is the most important funding institution in the field of applied research and product development. In 1999, the total funding of the two projects related to the field of information technology and telecommunications was EURm 178.6 (Salo et al. 2000: 9–10). About 60 percent of the project funding had been contributed by industry; *Tekes*' maximum contribution in general is 50 percent. The aim of *Sitra*, the Finnish National Fund for Research and Development, is to promote new innovative firms. In 1999, *Sitra* had 20 start-ups from the information and communication technology industry in its portfolio. They received EURm 19, which was 27 percent of *Sitra's* total investments. During the past ten years, *Sitra* has increased its finance for start-ups in the information and communication technology sector by 300 percent, and the number of participating firms has grown even faster.

Figure 6: Investments of *Sitra* in information and telecommunications technology in 1991-1998.



5.2 Education

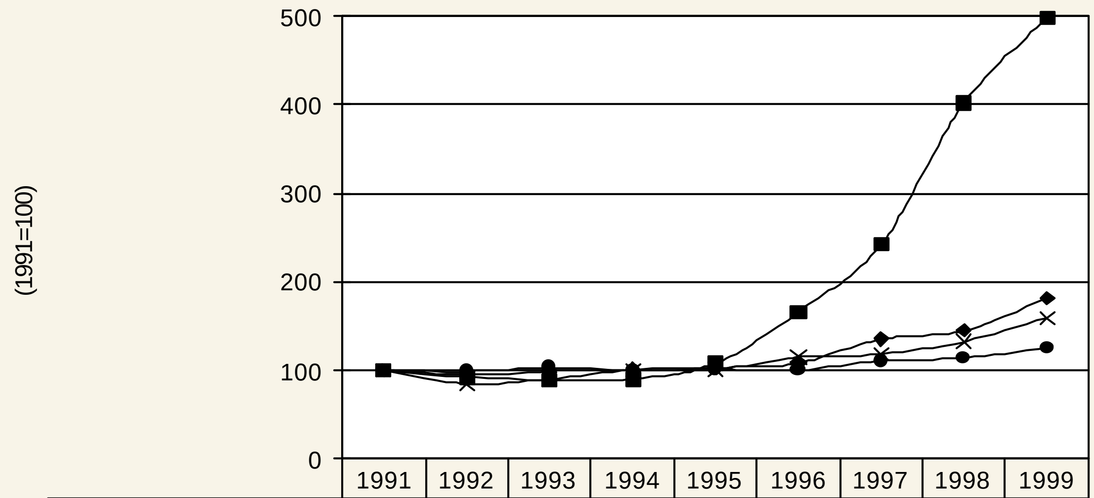
In the telecommunications sector, the need for an educated labour force is particularly high; most of the new jobs created in this sector require a degree at least on the polytechnic level (Mannermaa and Ahlquist 1998). In this industry, the share of less educated workers is continuously decreasing, while the level of education in the workforce is correspondingly rising. For example, at L.M. Ericsson's unit in Finland, where most of the people are working in R&D, half of them are engineers. It is argued that upper secondary training is not enough as far as adapting to change and continuously learning new things are concerned, as is the case in the telecommunications industry, where a solid theoretical basis is indispensable. This trend is also supported by the fact that production is increasingly moved out of Finland, while knowledge-intensive functions remain in Finland.

From the mid-1980s on, business people have criticised the low number of graduates specialised in telecommunications technology. Policy-makers have reacted to the shortage of skilled personnel by developing a programme to increase the number of student places in the information technology programmes of universities and polytechnics. In 2000, there were 3,800 student places in universities and 6,300 student places in polytechnics in the field of information technology, which is nearly 17 percent of the age group of the 19-year-olds. The programme also assumed that the so-called conversion education, in which professionals from neighbouring industrial branches or telecommunications professions with lower degrees receive a two-year education, is likely to expand.

In 1999, the Ministry of Education composed a new action plan "The Strategy of Knowledge of the Education and Research 2000 – 2004". The document, besides stressing the importance of further increasing the number of student places in information and communication technology education, also notes the very limited bases to further increase recruitment for tertiary level education in this field. To overcome the gap between the supply and demand of highly qualified people in the sector, Finland has started to acquire foreign students. In its new strategy paper, the Ministry of Education also stresses the importance of free adult education in information-society skills and in particular the need for the "new ability to read". The strengthening of these basic skills throughout the whole population has contributed to the fact that Finland is viewed by many foreign companies as an excellent test-market for new products, thanks to its highly competent customers.

Figures clearly indicate the rapid expansion of education in information and communication technology occupations. Including both upper secondary vocational education and tertiary education (universities and polytechnics), the number of students in information technology has increased significantly. While in 1985 the share of telecommunications students was 2.7 percent, in 1997 the share had already grown to 8.1 percent of new students, including all levels of education. But these figures also indicate a clear trend towards higher education. For example, the student boom of the 1990s has been most impressive in the education of telecommunications technologies. As Figure 7 shows, the rapid growth of the number of university students in the Finnish higher education system can, to a great extent be explained by the extension of the engineering education in telecommunications. Within less than ten years the number of university students in telecommunications engineering education has increased by about 500 percent. The development in polytechnics[10] has been equally impressive. The number of new students in information technology education has about doubled within the period from 1997 to 1999. The number of new students in upper secondary education, on the other hand, has dropped by about 30 percent within the period 1995–1997.

Figure 7: Students passing entrance examination to university education in Finland in 1991-1999



	1991	1992	1993	1994	1995	1996	1997	1998	1999
All new students	100	98	102	100	101	100	110	113	124
Engineering	100	94	98	101	102	108	135	144	181
IT Engineering	100	92	88	90	107	166	242	402	499
Computer Sciense	100	84	89	100	100	114	118	132	159

Source: SVT: Koulutus ja tutkimus. 1991:14, 1992:12, 1993:9, 1994:9, 1995:13, 1996:10, 1997:7, 1998:7, 2000:1

6. Competition and co-operation in the telecommunications sector

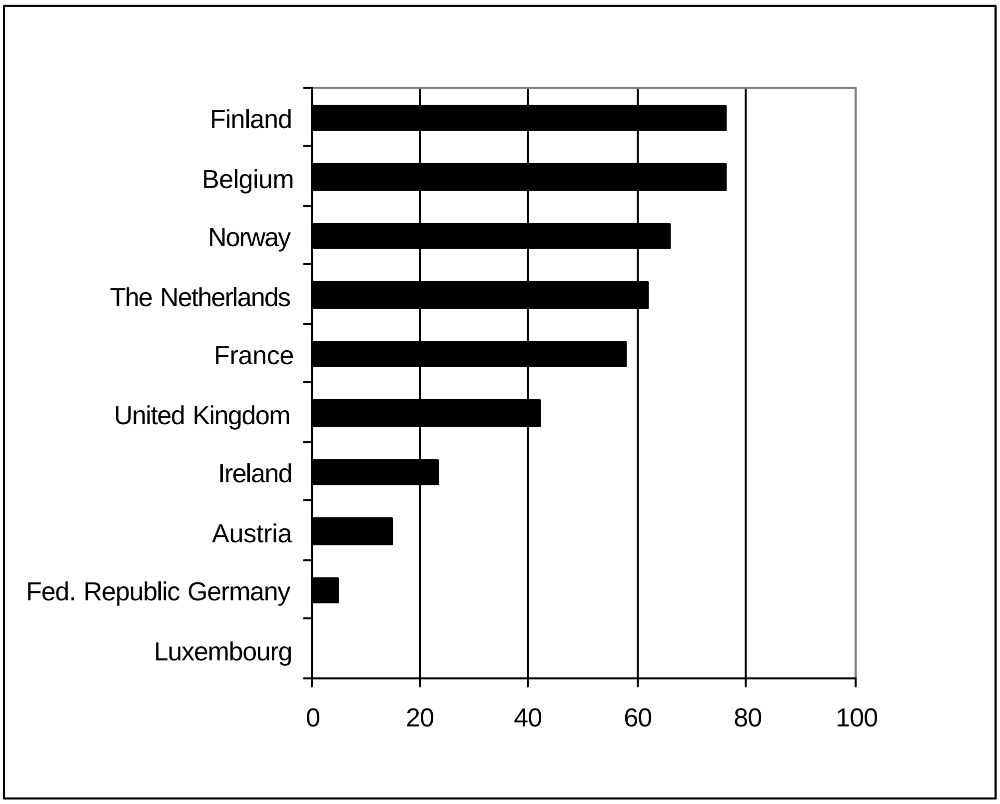
Earlier we characterised the situation in the Finnish telecommunications industry in the area of analogue fixed-line communication as relatively competitive. Both the decentralised system of network operators and the pressure of foreign competitors in the equipment industry can be seen as important elements of competition. Although the two camps among the telecommunications operators, the national PTT and the association of regional telcos, did not compete for market shares

[10] The main aim of the recent polytechnic reform is to educate new types of experts to correspond to the skill demands of the emerging knowledge economy. This means, in particular, that graduates from the polytechnics should have a strong practical orientation.

before liberalisation, they were engaged in a kind of technological race because they had to adapt to competitive pressures stemming from the rapid upgrading of the other camp (Palmberg 1997).
The existence of several foreign buyers in this has stimulated competition among the equipment producers, as they had to continuously upgrade their technology, increase the standards and keep their prices down to keep customers alert. Competition, we can conclude, was a crucial factor supporting the development of the Finnish telecommunications industry.

However, competition turned into co-operation as soon as Nokia became the dominant player in the Finnish equipment industry. As the Finnish telecommunications giant began to outsource parts of its business to secure further growth, the telecommunications industry turned into a network structure, where some of the outsourced companies became core suppliers to Nokia. Subcontractor and supplier relations of most Finnish equipment producers with Nokia may explain at least to some extent why co-operation in innovation processes is typical of the Finnish telecommunications sector (Figure 8).

Figure 8. Telecommunications enterprises with co-operation (% of innovating enterprises)



Source: Eurostat, Enterprise DG, 2nd Community Innovation Survey

However, as Nokia is developing into a key global player, the company's network of suppliers and subcontractors has passed national borders and worldwide co-operation becomes much more important. Due to this globalisation process, Nokia's idea-innovation networks include an increasing number of foreign companies and research institutes. On the other hand, Finnish suppliers and subcontractors, eager to tie in the worldwide production chain also became more global and began to supply to other large companies. And in addition to Nokia's direct subcontractors and partners, also second-tier suppliers have started to expand their operations globally forming new sub-networks to Nokia's global innovation and production network. Nokia, of course, also co-operates extensively with other global players, in the process of standards setting, for example. And in the world of the Internet, the company has started intensive co-operation with customers applying the open-source development model.

On the other hand, competition among network operators has increased. Due to liberalisation, the duopolistic market structure has disappeared and a few new competitors have entered the market. But there is still little international competition, although the Swedish Telia has acquired an UMTS licence. Sonera's attempt to find its place in the forming global alliances seems to have failed; the company's aim to develop into a technologically sophisticated service company with products that are international brands can probably only be realised under the roof of a strong global player.

It is well known that university-industry co-operation in Finland is very intensive (Academy of Finland 2000), which is also true for the telecommunications sector. However, the mode of co-operation has changed. The traditional knowledge-transfer model has turned into a collaborative process of knowledge creation and diffusion. We can speak of an increasing importance of the 'interactive research mode', where knowledge flows in several directions within innovation networks (Nieminen and Kaukonen 2001).

Finnish technology policy may have contributed significantly to the intensive co-operation among firms and with knowledge producers in innovation processes. The Finnish cluster programme, the network-enabling policy approach of *Tekes* as well as the regionally oriented Centers of Expertise Programme all aim at supporting network formation also in the telecommunications industry. In addition, *Tekes* and the Academy of Finland have started to launch joint research programmes which may even intensify co-operation between business and knowledge producers. There is also a clear tendency to support Finnish firms and other Finnish organisations tying up in global innovation networks and to acquire a strong position in these networks.

But for a small country like Finland, personal relationships may be even more important than organisational ones. There are very close personal ties among the engineers, industrialists, scientists and policy-makers working in the telecommunications sector that are supported by the high mobility of employees and managers in the field. People meet quite frequently in committees, project groups, conferences and seminars, and they often work together in a variety of different projects. Those processes of close and long-term co-operation have contributed to the accumulation of social capital, which in turn creates a trust basis and stimulates further co-operation.

7. Conclusion

Since the 1990s, when telecommunications became a stronghold of the Finnish economy, equipment producers have played a dominant role in the sector. Equipment production first changed from small-scale production dominated by a few foreign companies towards a diversified industry, in which Nokia soon became the key player at the same time as some small and medium-sized Finnish companies have also entered the market. The next phase of development can be characterised by an increasing internationalisation and globalisation process, during which Nokia developed into one of the dominant players in the world market. This meant a breakthrough, not only in respect to size and market coverage but also in respect to technological leadership. The role of foreign firms in the sector also changed significantly. While they earlier served as a channel for technology diffusion into Finland, their major role nowadays is to offer skills, channels and resources for exporting Finnish 'know-how' (Lovio 1993).

The segment of network operators and service providers also played a role in the development of the Finnish telecommunications sector. First, the decentralised system of network operators has shaped the development of the industry since it created an atmosphere of technological competition that forced the equipment producers to stay ahead in the technological development. Second, network operators and value-added network service providers themselves have formed a rapidly growing, though still small, segment in the telecommunications industry. Altogether, we can argue, the Finnish telecommunications sector has developed into one of the most advanced markets in the world in terms of technology, service variety and price efficiency.

There is no single explanation to the success story of the Finnish telecommunications sector. Instead, it is the interplay between several technical, economic, socio-cultural and geographic factors that has contributed to the current strength of this industry. We have already mentioned the competitive situation in the Finnish telecommunications on both the demand and supply side. Never in the history of the Finnish telecommunications industry has an equipment producer been in a monopolistic position as was the case in other countries. The national PTT and private local telcos have always made their own decisions when choosing the equipment for their networks. Therefore, equipment producers had to introduce better technology than other manufacturers to get their products sold.

One can assume that there is a specific connection between the great need for telecommunications resulting from the peripheral situation of Finland within Europe as well as its huge spatial extension, the early building up of networks, and the technological progress of the sector (Vuori and Vuorinen 1994: 12). Large remote regions in the Northern and Eastern part of Finland have suffered from migration to the south-west of Finland, and the development of an efficient telecommunications infrastructure was seen as absolutely necessary to keep jobs and people in the remote areas.

There are also cultural factors involved. The openness of Finnish people for modern technology has helped telecommunications to spread rapidly. Furthermore, what has been called the Finnish techno-nationalism (Myllyntaus 1990) may explain why Finnish engineers keep firmly at finding new technological solutions. And one can also assume that allowing for continuous and close interaction among core actors in the telecommunications industry, social capital which fosters interactive learning and collaborative innovation is more likely to develop in a small country like Finland than in larger countries.

Entrepreneurship, the preparedness of business people to take high risks and their strong early global orientation have been mentioned as decisive for the rapid development of the Finnish telecommunications industry. Also, government policy has played some role in the success, particularly the ‘new’ innovation policy based on the concept of the ‘national innovation system’, which has emphasised the need for high education, focused research as well as close interaction between universities, business, and governmental research institutes.

What are the future perspectives of the Finnish telecommunications industry? Nokia has reached the limits of continuing rapid growth in Finland: as there are no sufficient domestic resources for further development, most of Nokia's future growth will take place outside its home base. Therefore, to some extent, the further development of the Finnish telecommunications industry depends upon the growth perspectives of the small and medium-sized off-springs of Nokia. The question is whether they will be able to internationalise very rapidly and become global suppliers in their niche markets.

Nokia itself will face more difficult times, however. The fate of the company depends to a great extent on the rapid adoption and spread of the UMTS technology. Many experts, however, argue that Nokia's expectations of 3G taking off at the end of 2001 or at the beginning of 2002 are over-ambitious (Financial Times 2001). And due to the fact that mobile phone and handheld computers will merge, Nokia will be confronted with even tougher competition. On the other hand, whether Nokia will succeed with its new Internet business is still uncertain.

In the future, together with the development of the next generation of mobile telephones, it is the service producers and content providers that will lead the development of the sector. So far, Sonera has not been successful in presenting itself as a technologically sophisticated service company specialising in telecommunications and data exchange with products that are international brands. In addition, it does not have the needed financial resources to compete successfully with the huge global network operators. Therefore, the fate of Sonera is highly uncertain; on the one hand, companies have to proceed very rapidly to reap the prime-mover benefits; on the other hand, the growth potential of the sector is difficult to assess. The Finnish digital content industry in general is still in the early stage of its evolution (Ali-Yrkkö 2001).

Finland, while being a good example of how companies and countries can manage the transformation into the knowledge-based information society, may also become a good example of how national markets get blurred and become a segment of a global market. This of course questions the concept of 'national innovation system' and the policy related to its enactment and sustainability.

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ANNEX I. B1. BIOTECH GERMANY

The Emergence of the German Pharmaceutical Biotech Industry and the Role of the National Innovation System

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Country Sector study as part of the final report of the TSER-Project “National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries”

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Introduction

In the second half of the 1990s, the German pharmaceutical biotech industry developed from a latecomer into the most dynamic sector of its kind in Europe. In terms of commercialization of scientific knowledge, Germany surpassed Great Britain, which still has Europe's largest biotechnology industry. In 1999, Germany's biotech start-ups attracted a total venture capital sum of €260 million, the highest amount of early stage financing in Europe. With the establishment of 279 start-up companies in this sector between 1995 and 1999, Germany scored most formations of new biotech companies in EU member states, beating Britain, France, Sweden, the Netherlands and Finland into the following places (Deutscher Bundestag 2000, Ernst & Young 2000: 14-17).

Germany was able to catch-up in pharmaceutical biotechnology mainly due to significant changes which occurred both in the institutional environment in which the sector is embedded – especially in regulation, financing, and public policies – and in the organizational set-up of the innovation process as the result of the new technological paradigm of genomics-based drug development. The emergence of the German pharmaceutical biotechnology industry took place in three major phases.

The *first phase* lasted until the early 1990s and was characterized by the existence of only few small and medium-sized companies which were active as specialized technology suppliers for pharmaceutical firms. If any research was done, capacities remained very limited. In view of drug development, pharmaceutical companies as well as universities still adhered to the traditional path of chemistry-driven pharmaceutical research (Marschall 2000: 144 ff.).

The *second phase* took until 1997/98. Due to regulatory changes of the German genetic engineering law as well as a new approach in federal biotech funding, the dynamic of commercialization of scientific knowledge in biotechnology increased considerably. Initially, newly established small and medium-sized companies concentrated very much on contract research and the development of platform technologies for the big-pharma industry, especially because technology development was considered to be the less risky business strategy with which revenues could be generated in a very early stage.

In recent years, however, the industry clearly entered a *third phase* in which more and more firms engage in drug development programs both in cooperation with big-pharma and other biotech companies as well as by implementing fully in-house R&D programs. In the meantime, this new strategy has been supported also by the major financiers of the sector, since venture capital providers have recognized that drug development promises considerably larger revenues even if the risk of failure is high during perennial drug development processes.

This report concentrates very much on the analysis of the development of the German pharmaceutical biotech industry since it has entered into the phase of transition from the second to the third phase. By doing that, we try to revue major findings from various socio-economic studies on the German biotech sector which have focused so far on the second phase of the industry's development process. *Caspar* and *Kettler*, for example, have argued that Germany's biotech companies are centered in the platform technology market segment due to a "comparative institutional advantage" which arises from the country's traditional model of "non-market business coordination". Since this model favors incremental and lower-risk innovations, the authors predict that "German firms are not likely to be able to make in-roads into the high-return, but high-risk 'blockbuster' segments of therapeutics" (2000; cf. also Giesecke 2000). *Momma/Sharp* have pointed in a similar direction analyzing that the German industry is much stronger in equipment and environmental biotechnology than its British and U.S.-American counterparts. As a conclusion, they have argued that German biotech companies are more specialized towards market niches and they have related this development to the country's traditional institutional comparative advantage in diversified quality production (1999: 280).

However, our findings support conclusions of more recent studies which have stated that the concentration on platform technologies used in pharmaceutical biotech was due to the late development of the industry in Germany which started from a comparatively weak and fragile basis. Since the development of therapeutics requires that a firm already has established core competencies and stable relationships with other actors in the field (academic research institutions, clinics, pharmaceutical companies) the initiation of drug-oriented R&D programs was all but likely in the first or second phase of the development path of the German biotech industry (cf. Krauss/Stahlecker 2000: 19).

All in all, the most important steps in the development of the German pharmaceutical biotech industry since the mid-1990s have been taken only after new regulatory approaches have occurred at the national and the European level. These approaches, which were aimed at easing the commercialization of biotech research, will be described in chapter 1.

Apart from changes in the regulatory regime, public policy has contributed significantly to the emergence of the German pharmaceutical biotech industry especially through the implementation of an innovative technology program at the national level which was organized as a competition of regional clusters for federal funds. This program, called *BioRegio* program, is described in more details in chapter 2, in which we will argue that a major reason of the success of the program was the existence of two strategic elements. The first element was the approach to provide money only to those regions which were able to establish a network structure involving all relevant private and public actors. The second strategic element of the program was the preferential treatment of those regions which already had an established research infrastructure in biotechnology.

In Chapter 3 we will argue that the development of new patterns of financing of innovations in pharmaceutical biotechnology was crucial for the establishment of innovative small and medium-sized biotech companies. These start-up companies depended (and many still depend) heavily on venture capital from both private and public sources.

Chapter 4 deals with the German education and research system. In view of the pharmaceutical biotech industry, these systems can be described as both an important facilitator and a hindrance for the dynamic development of a science-based industry. They have clearly supported this industry through the provision of highly-qualified researchers who have established small biotech companies mostly as spin-offs from non-university research institutes. However, today there is a significant lack of human resources both in view of researchers as well as technical personnel.

The fact that the German pharmaceutical biotech industry did not stick in niches, but is clearly orientated towards drug development can be traced back to organizational innovations and the ways and means research is managed in the pharmaceutical industry under the new technological paradigm of genomics-based drug development. As argued in chapter 5, small and medium-sized biotech companies were able to step into the idea-innovation chain of modern drug development and they thus closed a technology gap which occurred in the early phases of the chain. Biotech SMEs have been able to link pure basic research mostly done by academic research organizations with the needs of traditional pharma companies which are suffering from the lack of certain knowledge and, therefore, were eager to shift the risky and costly phases of the innovation process to external providers.

In our conclusions, we will argue that despite its dynamic growth in the last five years, the German pharmaceutical biotech industry is still behind its major competitors in the United States and Great Britain. In order to close this gap the leading German biotech companies have to grow internally since the whole industry has entered a phase of consolidation. Public policy engagement will be of importance even after the successful establishment of a biotech industry in Germany, especially in view of the provision of funds for basic research which is the most important source for qualified personnel as well as knowledge and ideas which can be brought to the market.

1. Changes in the regulatory regime for pharmaceutical biotechnology

Until 1990, a single regulatory framework for genetical engineering did not exist in Germany. The authority to approve respective laboratories or production facilities rested with regional regulation bodies which decisions in favor or against genetical engineering very much depended on political majorities in the federal states. The first attempt to initiate national "regulation" for the biotech sector was made in 1986 when the *Robert-Koch-Institute* issued a guideline which qualified biotechnological research and production as exceptional cases from the federal air pollution law ("Bundes-Immissionsschutzgesetz"). Companies were thus allowed to become active in the field if they agreed to bind themselves voluntarily to this guideline.

However, given the broad public skepticism about genetical engineering in Germany, both companies and opponents called for a national law, the former ones because they had predictable legal standards as a precondition for their activities in mind, the latter ones because they thought a national law could be used to impose tight restrictions. In view of the companies' call for a national law, there is one well-documented case which shows that at least the establishment of genetic engineering production facilities failed because of the non-existence of respective regulation. In 1989, the Administrative Court of Hesse decided against an authorization which would have allowed the pharmaceutical company *Hoechst* to establish a genetical engineering based production facility for human insulin. In their opinion, the Court argued that as long as no legislative act explicitly permitted the use of genetical engineering, no research or production facility could be established regardless of how the potential risk of an individual facility might be assessed (Aretz 1999: 245 f.). This judgment along with the decision of Hoechst to establish the facility in France increased the pressure on the federal government to initiate legislation on genetical engineering.

Until 1990, two federal laws went into force which regulated various aspects of genetic engineering in Germany. The first one, the *Embryo Protection Law* ("Embryonenschutzgesetz") prohibited researchers from using embryo for genetic experiments. The second one, the *Genetic Engineering Law* ("Gentechnikgesetz") set legal standards for the authorization of genetic engineering laboratories and production facilities and regulated field trials with genetically modified organisms. It was thought to be a compromise between commercial interest in biotechnology and the disapproval of genetic engineering by various groups in German society.

Compared to U.S. standards, the law was certainly more restrictive especially in view of public participation in administrative authorization procedures. The law nevertheless provoked sharp criticism from opponents of genetic engineering. Many big-pharma companies, especially *Bayer* and

Hoechst, moved their genetic-related research and production primarily to the U.S. as a reaction to the new laws.

At first sight, the tight regulations of the 1990 genetic engineering law did not only force companies to go abroad, in case of smaller companies, which stayed in Germany, it even caused cutting biotechnology activities at all. Although most descriptions of biotechnology in Germany – even official statements (cf. BMBF 2000a: 58) – follow this argumentation, there is room for skepticism.

According to an expert in the field, there is a different interpretation about the actual impact of the genetic engineering law plausible. Germany's pharmaceutical industry has traditionally been strong on world markets and has been able to keep a global market share of at least 40 percent over decades. Its research was chemistry-driven and did not anticipate the impacts of genetical engineering on drug development and food production until U.S.-based biotechnology companies started to market their products in the mid-1980s. As a reaction to that, many German big-pharma companies established research facilities in the U.S. and reduced their related efforts in Germany. This indicates that at least some companies which had recognized that they had fallen behind in genetical engineering tried to catch-up by investing in R&D outside Germany under the pretext of unacceptable regulations at their home base.

Regardless of whether the federal genetic engineering law actually forced traditional pharma companies to conduct biotechnological R&D and production outside Germany, it certainly imposed barriers to the commercialization of scientific knowledge which existed especially in non-university research institutes. As a result, the political debate over the country's competitiveness in this sector was intensified only a short time after the enactment of the law. In 1993, the genetic engineering law was revised in order to reduce administrative hurdles for the authorization of biotechnological research and production. This holds true especially for research and development facilities which normally fall under the lower risk categories. For those facilities summary proceedings were introduced which do not require anymore either public participation or special authorization by a federal commission for biological safety. In 1996, a second revision of the federal genetic engineering law which was already influenced by regulatory activities at the European level, further deregulated the sector and brought national regulations in line with U.S. standards.

2. The BioRegio contest: the starting signal for the commercialization in pharmaceutical biotechnology

Germany's position as a latecomer in the commercialization of biotechnology does not indicate that public policy was not early enough engaged in this field. On the contrary, Germany was the first country at all that implemented a publicly funded research program in biotechnology in 1972. However, early public investment in biotech R&D did not prevent that a country known as the "pharmacy of the world" lost ground in an emerging technology. During the 1980s, Germany fell significantly behind other industrialized nations in terms of the existence of small or medium-sized biotechnology companies. Whereas in 1984 245 such companies existed in the U.S. and 157 in Japan, Germany had only 15. Even five years later the situation did not change to the better. The number of biotech SMEs had further increased in the U.S. to 388 in 1989 while only 17 were active in Germany.

One reason for that development certainly was the chemistry-driven research tradition of big-pharma companies. This tradition was not only reflected by strategic decisions of corporate actors concerning their R&D programs, it also influenced public R&D policies since the Research Ministry invited the leading industry association, the DECHEMA (German Society for Chemical Engineering), to define the policy goals. The DECHEMA, along with their corporate members, proposed to support traditional second generation bioprocessing, but not third generation post-DNA recombination which was already on the research agenda in other countries (cf. Adelberger 2000: 107 f.). The second reason was that public policies did support R&D efforts of the industry, but was not active in providing incentives for commercialization of scientific knowledge which consequently did not step out of its traditional places, universities and non-university research organizations. Nevertheless, the federal government did invest in the academic infrastructure and established four national centers for genetic research in Berlin, Cologne, Heidelberg, and Munich. The selection of these locations was not by accident, but aimed at strengthening those regions in which scientific infrastructure (i.e. universities and Max-Planck-Institutes) was already strong.

The situation changed significantly when the federal government initiated the BioRegio program in 1995 and simultaneously proclaimed a pretty ambitious goal: to become the leading biotech nation in Europe by the year 2000. Indeed, the BioRegio program was itself an innovative policy tool which had no model at that time, but has been copied by many countries afterwards. The BioRegio program actually was a contest aimed at stimulating the creation of biotech clusters and thus the commercialization of scientific knowledge.

A total number of 18 regions entered the contest and had to demonstrate that they were able to set up a working and interacting infrastructure for the commercialization of biotechnology. The Federal

Ministry of Education and Research (BMBF), which was responsible for the program, designed the contest in a way which clearly favored locations which infrastructure was already developed. Behind that strategy was a political intention to further strengthen already strong and established locations. As a result, the three winners of the contest – the bioregions around Cologne ("BioRegio Rheinland"), Heidelberg ("BioRegio Rhein-Neckar-Dreieck") and Munich – were already favored in the 1980s through the establishment of 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 in all four regions between 1996 and 2000 and invested a total sum of DM 141 million.

In fact, the *BioRegio* program was able to initiate the commercialization of biotechnological research not primarily by the provision of funds. The more important factor clearly was the establishment of a network structure in the different local clusters which involved all relevant private und public actors. In Munich, for example, networking activities largely depend on one central actor, the *Bio-M AG*, which was founded in 1997 and originated from the publicly-funded initiative committee that prepared Munich's application for the BioRegio contest. Today, the shareholders of the Bio-M AG are banks and venture capital firms (initial investment: DM 4.7 million), pharmaceutical companies (DM 4.45 million), the state of Bavaria (DM 3.75 million) and private investors (DM 1.3 million). The Bio-M AG has to business activities: the provision of venture capital and the establishment of a network for consultancy and information. In view of the first business activity, Bio-M is working profit-oriented; the second business activity is supported by the public funds from the federal and state level. This business activity makes Bio-M to the center of the Munich biotechnology network. The Berlin biotech cluster, however, was the only location where a National Gene Center exists, which did not succeed in the BioRegio contest, especially because of the lack of public financial support for a central networking actor.

3. New patterns of financing science-based industries: the emergence of a venture capital market in Germany

The biotech sector, in which most of the start-up companies are established as spin-offs from academic research and in which – at least when the company is engaged in drug development – enormous R&D investments are necessary in order to bring a product on the market, certainly is the most capital intensive high-technology industry. Therefore, the development of a biotechnology sector depends heavily on the availability of capital, regardless whether it is provided by public or private institutions.

Traditionally, Germany had a bank-centered financial system in which economic activities are funded primarily by firms that finance expansion through profits or by banks which grant loans to those companies which proved their credit-worthiness through their corporate performance in the past (Adelberger 2000: 113). Whatever way, bank-centered financial systems are regarded to be disadvantaged to produce radical innovations or to promote a start-up industry over a system which is based on the availability of venture capital and the existence of high-tech specialized stock exchanges which are important as an exit-option for risk capital providers.

The dynamic development of the German biotech sector underlines how important venture capital is for the expansion of high-technology industries, and thus verifies that the times of a bank-centered financial system in Germany are (long) over. However, that does not mean that the dynamic development of the biotech sector in Germany is largely the result of the existence of private risk capital. On the contrary, since the mid-1990s it has been the result of state intervention not only to establish the framework conditions for the provision of private venture capital, but also to act itself as a venture capital provider. In Germany, the relation of private and public risk capital within the biotech industry is 1 to 0.8. This figure, which is by far higher than in the U.S. or Great Britain, demonstrates the importance of the public sector for the provision of venture capital (Ernst & Young 2000: 126).

Actually, the state does not act as a venture capital provider in a narrower sense, but allows for re-financing of private risk capital through public financial institutions such as the *Kreditanstalt für Wiederaufbau* or the *Deutsche Ausgleichsbank*. Both institutions jointly created the *Technologiebeteiligungsgesellschaft* (tbg) which has issued a number of equity capital programs since 1989. Between 1989 and 2000, the tbg offered more than €250 million to private venture capital companies (Adelberger 2000: 115).

The importance of public risk finance activities for the development of an innovation biotech industry can be demonstrated even at the regional level. In the early phase of commerzialization, when private venture capital firms were not that much engaged in Bavaria, the public VC-agency *Bayern Kapital*, a company in which the State of Bavaria holds 100 percent of the shares, provided early stage seed capital to biotech start-ups in the Munich area. In the meantime, more than 20 private venture capital firms and Investment Banks which invest in the biotechnology sector, have been established in Munich, whereas *Bayern Kapital* has been able to reduce its efforts for pharmaceutical companies in Martinsried and now concentrates more on commercialization of biotech scientific knowledge at other locations in Bavaria. Many start-up biotech companies in the Munich area have been initially funded by a co-investment of a private VC company, an investment by the *Technologie-beteiligungsgesellschaft*, an investment by *Bayern Kapital* and project-based funds provided by the *bmbf* or the *Bavarian Ministry of Finance*.

Germany's venture capital market has increased significantly since the mid-1990s. In 1998/99 a total sum of €1.2 billion was invested into the biotech sector, in the year 2000 the total amount of venture capital in Germany reached €6.4 billion with a share of more than 30 percent reserved for the biotech industry. All in all, since 1998 about 10 out of at least 37 venture capital funds have spent at least half of their capital for biotech investments.

German biotech companies still rely heavily on external financiers. This holds true especially for drug developing companies which have to pre-finance R&D programs that can have a duration of up to 15 years. During this period, the amount of internal cash-flow largely depends on revenues originating from cooperative drug development programs with big-pharma (royalties or milestone payments) or from licensing or selling platform technologies or services. In 1999, Germany's small and medium-sized biotech companies generated about 46 percent of their capital out of their own business activities. The majority of capital, however, was provided by venture capitalists and public institutions or – in case of already publicly listed companies – has been the result of an IPO.

An important pre-condition for the provision of risk capital as well as for further external flows of capital for biotech companies is the existence of a stock market specialized on high-technology start-up companies. Venture capitalists need the stock market as an exit-option for their investment, while biotechs are able to reduce their dependency on further venture capital through an IPO. The *Deutsche Börse AG* established a high-technology stock market in 1996 with the foundation of the *Neue Markt* located in Frankfurt/Main. In March 2001, 17 companies were listed to the biotech index of the Neue Markt, most of them are engaged in the licensing or selling of platform technologies and services. Only three of all these companies, GPC Biotech AG, Medigene AG, and Morphosys AG, all located in Martinsried near Munich, are explicitly committed to the development of drugs. Today's composition of the Neuer Markt biotech index insofar reflects the early strategy of venture capital companies to chose the low-risk strategy and to finance primarily those biotech companies which are engaged in the development of platform technologies.

4. Both facilitator and hindrance: The German research and education system

The public R&D infrastructure certainly plays a more decisive role in biotechnology than in a lot of other industrial sectors. On the one hand, research in biotechnology can be characterized in many aspects, such as the mapping and sequencing of the human genome, as basic research whereas, on the other hand, especially non-university research organizations as well as universities were and still are the most important actors in view of the commercialization of scientific knowledge in biotechnology.

Publicly financed research and development in biotechnology takes place at universities as well as at institutes of the Max-Planck-Society, the Fraunhofer Society, the Helmholtz Society, at some of the so-called blue list institutions (now the “Wissensgemeinschaft Gottfried Wilhelm Leibnitz”, WGL) and at some of the departmental research organizations directly financed by ministries of the federal government or the federal states. Additionally, the European Molecular Biology Laboratory (EMBL) in Heidelberg is active in biotechnology as well.

Universities and non-university research organizations were of special importance for the commercialization of biotechnological research since most of Germany’s small and medium-sized biotech companies have been established out of publicly funded research organizations. In the Munich biotech cluster, for example, about 30 of the total 54 biotech start-ups originate from one of the three leading research organizations in the area: the Max-Planck-Institute for Biochemistry, the GSF Research Center, and the Gene Center of the Munich University. Three of them have been founded by researchers of at least two of these institutions.

Traditionally, universities are important actors in basic research in various academic disciplines. Since most of the universities which have departments of biology, chemistry, medical sciences etc. are active in any field of biotechnology it is hardly possible to determine the number of chairs or research groups and their specific research interest. However, according to the German Statistical Office, 450 university institutions were involved in biotechnological research in 1995 (European Commission 2000b: DE-24). About 48 universities offer programs of study in biotechnology, of which 20 are more oriented towards technical aspects, the other 28 more towards studies in biology, microbiology or biochemistry. In addition to that, about 16 universities of applied sciences (polytechnics) have started programs in biotechnology in recent years.

According to the nature of biotechnological research, the most important non-university research organizations in the field is the Max-Planck-Society (MPG). In January 2001, the MPG maintained 79 research institutes which employed roughly 9,500 scientists. In the wider area of biological and medical research, the MPG possesses 34 institutes or research groups. In recent years, the MPG has put special emphasis on biological research and concentrated about a third of its total expenditures in research funding on this sector. In 1999, biological research was financed with a total sum of €325.9 million. Other research organizations, such as the Fraunhofer Society, the Helmholtz Society or the so-called Blue-List Institutes are considerably less involved in biotechnological research, either because of their focus on applied research or because of their concentration on research areas which require an extensive technical infrastructure.

As an interdisciplinary and science-based industry, modern Biotechnology requires the existence of qualified personnel not only from various disciplines, but also with different levels of education and different areas of knowledge. This is especially the case in a highly dynamic market environment in which the lack of certain competencies both in quality and quantity can hinder the development of an industry. Looking at the German biotech industry, one can identify some areas in which qualified personnel is not available as required. One area concerns the discipline of bioinformatics. Since bioinformatics is a relatively new discipline, the German university system – comparable to the situation in other countries – has not been able to offer specialized programs in this field. Only recently, many universities and polytechnics have started programs in bioinformatics, however, it will take up to four years until students will be available for the industry. Other countries, especially the U.S., reacted in a different way. In order to bring qualified personnel early into the industry, they just have combined existing programs for informatics and biology or biochemistry and thus reduced the time in which students qualify for a degree in bioinformatics. Concerning the number of students who enter the universities for studies in natural sciences it is predictable that the German biotech industry will be confronted with a lack of qualified personnel at least in the field of chemistry. However, this might be compensated by an increasing number of graduates in the fields of biology and medical sciences (BMBF 2000b: 19).

A most recent OECD study has revealed that the entry rate to tertiary education in Germany is significantly lower than in other countries and also well below OECD average. In 1999, only 28 percent of young adults in Germany studied at an university or a polytechnical institute. In comparison, the OECD average is at 45 percent, while in countries such as New Zealand or Finland, more than two thirds of young adults are engaged in tertiary education. However, countries which have a strong system of secondary education usually have lower numbers of students in tertiary education. Nevertheless, in 1999 the total number of graduates in Germany was considerably lower than in other OECD countries. Whereas the OECD average is 920 graduates per 100,000 employees, in Germany there were only about 700. As a consequence, the German university system has started reforms which are primarily aimed at the shortening of university studies through the introduction of bachelor and master study programs. In the meantime, more than 1,000 of such programs have been created at German universities (BMBF/KMK 2001).

From corporate side, the German university system is further criticized because of its relatively low international orientation. Since only few universities offer courses in English language, it is hardly possible for foreign students to study natural sciences in Germany. Consequently, the lack of qualified scientists in the German biotech industry can hardly be compensated with foreign students or scientists. Moreover, scientists who decide to commercialize a certain discovery originate primarily from non-university research organizations, but not from universities. The main reason for that development is that post-doctoral graduates employed by universities largely depend on the research areas and interest of their academic chair and are not able to apply for their own research funds. Non-university research organizations, however, have changed their respective policies in recent years (especially the Max-Planck-Institutes) and offer young scientists the opportunity to join independent research groups.

A lack of qualified personnel has also occurred at the level of technical assistants (MTA and PTA) who are increasingly required to work in biotech laboratories. Traditionally, technical assistants have been educated within the vocational training system and have later been employed mostly within the medical system (i.e. hospitals and drug stores). As a result of the dynamic development of the biotech sector, most companies are not able to employ technical personnel according to their needs. Moreover, since demand is still growing, mobility of technical personnel is increasing because of the opportunity to realize a higher salary in a new job.

5. The organizational dimension: how innovative small and medium-sized biotech companies bridge the technology gap in genomics-based drug development

Under the technological paradigm of genomics-based drug development, new phases have been added to the idea-innovation chain in modern pharmaceutics. These new phases have been described as functional genomics which is now at the beginning of the innovation process, in which potential targets for the development of modern drugs and therapies are identified and validated. Traditional pharma companies were reluctant to use functional genomics. At first, they relied for a long time on chemistry-driven drug development programs. Later on, when functional genomics was recognized as the new technological paradigm, they preferred to outsource these functions because their lack of knowledge would have caused high entry costs. As a result, small and medium-sized biotech companies were able to step into the early phases of the innovation process and they are engaged in these phases in various ways.

A first group of companies develops and markets platform technologies for individual steps within these phases, such as high-throughput screening or bioinformatics. A second group provides large substance libraries which are used for the process of compound testing against targets. A third group of firms is engaged in the identification and validation of targets, either under contract for traditional pharma companies or in order to initiate their own fully in-house drug development programs.

Regardless of whether a biotech company is engaged in drug discovery and development or whether it is focusing on platform technologies, partnerships and alliances primarily with established pharmaceutical firms are equally important. On the one hand, those partnerships are essential to generate revenues, to stabilize the internal cash-flow, to create resources for in-house R&D programs, and to reduce the dependency on external capital. On the other hand, being selected by a big-pharma company as a partner in drug development or as a supplier for certain services or technologies underlines that the biotech company has gained ground in competition with important national and international biotechs. In that way, these alliances are an integral part of the biotechs' business activity and strategy.

Roughly speaking, there is a typical business model for most of the biotech companies which are active in the pharmaceutical branch of the sector. This business model can be described as the development of a firm from a technology supplier to a drug developing company. Normally, biotech start-ups enter the market as a spin-off from academic research commercializing first a certain platform technology or tool. In case that a company decides to enter into drug development, it will seek strategic alliances or joint ventures with big pharmaceutical companies in order to develop the drug candidate in cooperation and thus sharing the financial risks during the R&D phase. The ultimate goal, however, is to reach a position in which the firm can set up individual drug development programs financed by internal cash flow which originates from licenses for their technology or royalty payments out of cooperative drug development programs.

This business model copies the example of successful U.S.-American biotech companies such as *Amgen* or *Biogen* which were able to develop into biotech-driven pharmaceutical firms. Apart from the fact that this business model has proved to be successful in the U.S., it is quite obvious that the market itself prompts many biotechs to shift from a platform technology supplier into a drug developing company. For pure technology suppliers, attracting external capital is going to be more and more difficult since investors are more interested in companies which have the potential to develop a blockbuster therapeutic. Moreover, there is already pricing pressure on some technology services such as the identification of targets.

However, there are some companies in the German biotech sector which are doing well in some market niches. *Qiagen*, for example, is a world-market leader for a certain purification system, whereas *LION Bioscience* is a bioinformatics specialist which develops high-performance systems for the identification and validation of targets. Other companies concentrate or have a strong position in new fields of biotechnology such as biomaterials.

The fact that more and more German biotech SMEs are today focused on drug development underlines that the industry has entered the third phase of its development. Firms which do not have such programs and instead decided to specialize in a certain platform technology were able to gain ground even in competition with companies in the United States or Great Britain. This third development phase is also characterized by an increasing integration of German biotech companies into the global pharmaceutical R&D system. Since 1998, the number of strategic alliances, in which German biotech SMEs are involved, has been increasing considerably, by nearly 100 percent between 1998 and 1999 alone. Most of the strategic alliances in which the three leading Munich-based biotech companies (*Medigene*, *GPC Biotech* and *Morphosys*) are involved, deal with drug development programs. Moreover, between 1999 and 2001, five German biotech companies (Munich-based *Medigene* and *GPC Biotech* as well as *Qiagen*, *Evotec Biosystems* and *Lion Bioscience*) acquired biotech companies in the U.S. and Great Britain and thus gained access to the industry's lead markets and got special knowledge into their companies which was hardly available on the German market (especially in bioinformatics).

For German biotech companies, cooperations and alliances have a strong international dimension, but also regional and local one. The industry is highly decentralized and mainly clustered around the four leading locations in Berlin, Cologne, Heidelberg and Munich. Biotech firms obtain many of their resources out of these clusters. This holds true especially for start-up companies which are used to settle in the immediate neighborhood of the research organizations out of which they have been founded. In the Munich area, for example, many companies have exclusive access to the technical infrastructure of publicly funded research organizations. Many supporting institutions have been established in the neighborhood of the biotech cluster, such as technology transfer offices, patent lawyers, management consultancies, clinical consultancies, incubators etc. However, research cooperation between different actors within cluster (especially among firms) occurs only in rare cases. In view of the Martinsried cluster, only one such cooperation has been established between *GPC Biotech* and *Morphosys*. In this alliance, Morphosys tests antibodies against a number of *GPC's* targets. Even in publicly funded research projects, most actors in the Munich biotech region have chosen regional partners only in a limited number of cases. The analysis of biotechnology-related projects funded by European R&D programs shows that the projects with more than one actor of the Munich biotech cluster are clearly outnumbered by projects with only a single regional actor. This applies especially to the local universities and non-university research organizations which participate in a large number of projects.

6. *Conclusions*

After half a decade of enormous increase of small and medium-sized pharmaceutical biotech companies in Germany, the industry has entered into a phase of consolidation. This consolidation is characterized on the one hand by decreasing numbers of new company formations while, on the other hand, most companies, which have been established in the 1990s, are fostering internal growth in terms of employees, revenues originating from cooperative research programs and progress in independent R&D programs for innovative pharmaceuticals. The development of the Munich biotech cluster for pharmaceutical biotechnology in Martinsried very much illustrates this change from external to internal growth of the industry. The number of total companies has remained constant since 2000, whereas the number of employees has steadily increased and is expected to increase by about 80 percent in the immediate future. It has been estimated that the Munich biotech companies would require about 1,000 scientists and 700 technicians until 2003.

The lack of qualified personnel points at two important developments within the biotechnology industry. Firstly, given the high degree of internationalization in this sector, there is a competition at least for scientific employees which exists among the 40 or so biotech clusters around the world (BioM 2001: 3). Secondly, as a consequence of the increasing industry's demand for scientific employees, universities and non-university research organizations find it more and more difficult to attract young researchers at postgraduate level which is problematic both for basic research as well as for further commercialization of biotechnological knowledge.

It is widely accepted that biotech 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.). In view of many German biotech clusters it can be stated that commercialization of scientific knowledge has started late especially in comparison to the U.S. and Great Britain. Experts in the field estimate that the German biotech industry is 3-5 years behind its British counterpart and at least 10 years behind the U.S. biotech industry. This can be illustrated by the fact that the market capitalization of *Amgen*, one of the top-three biotech companies in the U.S., is higher than the market capitalization of Germany's largest publicly listed company, the *Allianz Insurance Group*.

The delay in commercialization of biotechnology in Germany 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.).

The delay in commercialization, however, does not necessarily indicate that German biotech clusters and especially the Munich cluster lack certain location advantages. On the contrary, according to a most recent analysis, which is based on a statistically weighted assessment of various indicators for location qualities, the Munich area is the leading biotech region in Europe and it also shows a remarkable strong competitive position even to biotech centers in the United States. One important factor is the existence and outward-orientation of universities in the Munich biotech cluster which is comparable to the academic infrastructure of California or South East England.

In comparison to other European locations, the Munich area scored most in the attraction of biotech companies. The most important weakness of the location is the availability of qualified employees which is, however, a problem in most of the biotech clusters. In view of the European biotech industries, the four leading German biotech clusters are ranked on the top five places and they compete especially with the British biotech region around London, Oxford and Cambridge. Locations, such as Southern Finland or Vienna suffer from especially from limited investment and technology grants and an university infrastructure which seems to be unprepared to meet industry's needs. The biotech region in the Northern Netherlands scored relatively well in view of most of the indicators, but nevertheless failed to attract biotech companies.

A catch-up strategy for the German biotech industry requires comparatively strong performance in five important 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, as many experts put it, its most important role is the provision of an adequate infrastructure for publicly funded basic research as it is a precondition for commercialization of scientific knowledge and the development of a biotech cluster.

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ANNEX I. B2. BIOTECH AUSTRIA

Austrian Biotechnology - Where to Find it on the Map?

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With thanks to the researchers Herman Oosterwijk and Stefanie Rossak who conducted the interviews and wrote a major part of the longer biotech EU report on which this paper draws.

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Introduction

There are rumours that Austrian biotechnology is non existent on the map. However, when looked from closer one can see some very dynamic firms in this sector. Austria managed to establish itself in some niches of red biotechnology. With the help of the city government of Vienna biotechnology got some technology push promotion. National institutions - in particular a lack of finance for start ups, a non adjusted technology policy and low public funding, and a petition that led to the prohibition of field trials can mainly be seen as a hindrance to the development of the sector. The more surprising that Austrian biotechnology reappears on the map.

In the following it will be argued:

1. That Austrian biotechnology does exist. The few firms and their activities will be surveyed in order to present the sector.

2. That Austrian firms are specialised on red biotechnology and that this is no coincidence.

3. That the pharmaceutical companies for whom the new technology is a matter of survival have developed certain strategies to get into biotechnology.

4. That national institutions play an important role as a promoter of the sector.
Here, the efforts of the city of Vienna government to establish a biotech cluster will be discussed.

5. Is the Vienna biotech cluster a copy of the Munich cluster? The parallels and differences, in particular the hampering institutions in Austria will be shown. Austria lacks a coordinated policy, lacks the enormous research funds and research centers Germany has available, lacks adequate finance for small start ups. Nevertheless, successful niches could emerge.

We can therefore question whether there are competent lobbies at Ernst and Young to put Austrian biotech on the map in future reports.
The following paper is based on interviews with experts that mirror the profile of the sector. They include large and small, startups and established companies, representatives of ministries, intermediary institutions, associations and universities. Interviews concentrated on the Vienna region.

1. The Austrian Biotechnology Sector

1.1. Austrian Biotechnology - Lower Performance and Small

Compared to Germany, the Netherlands and Finland, the Austrian biotech sector is small. It is so small that the Ernst and Young Report of 2000 does not even mention Austria separately anymore. It is listed in the rubric of "other countries". Since 2000, Austrian biotechnology is thus not to be found on the map in the biotech landscape anymore. However, insiders of the sector complain that Austria would deserve at least to be mentioned. They attribute the low performance (neglect) in the report to the fact that the sector description does not include some Austrian companies that are successfully engaged in modern biotechnology.

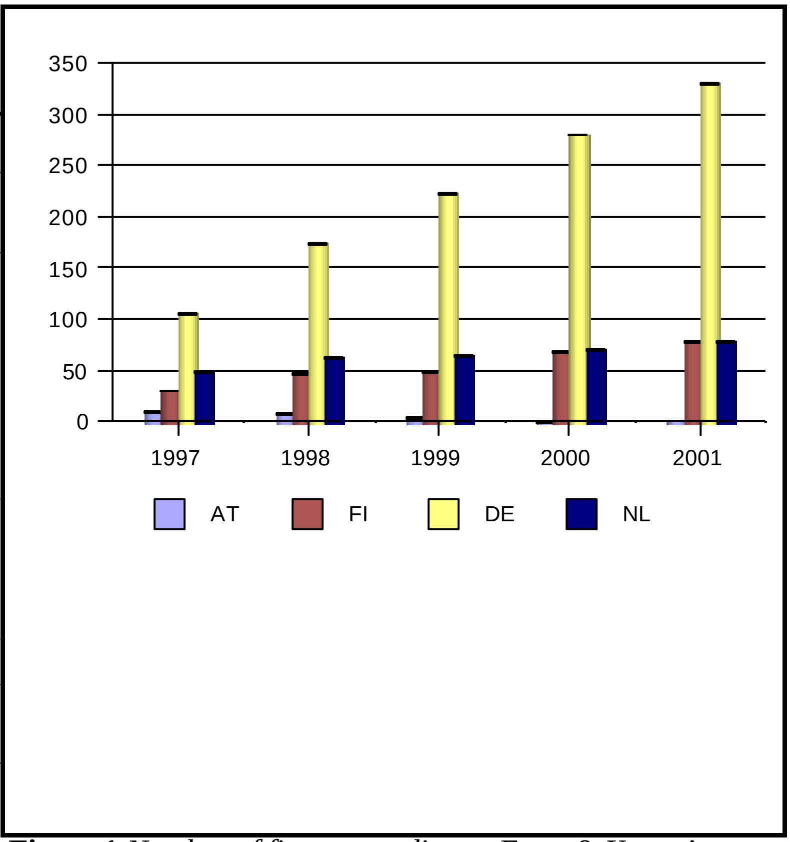

Figure 1 *Number of firm, according to Ernst & Young's European life science reports 1997 - 2001*

To give an example: the fermentation company Kundl (beer brewing) was active in classical biotechnology but could use the fermentation know how for the production niche of oral penicillin. It became the first company for oral penicillin worldwide and switched to genomics. Today, Kundl belongs to Novartis. But it was not included in the Ernst and Young report. "Austria has a good profile to those who know about biotech" (Interview Novartis).

But despite the existence of some very dynamic firms and start ups, when compared with the three other countries, Austria ranks lowest. The following table lists the development of the number of biotech firms between 1997 and 2001 in the four countries. Abstracting from the problems that can arise when comparing the number of firms in such a heterogenous field, Germany shows a booming development in the number of firms. Its heavily funded regional cluster policy seems to attract new entrants. Germany is followed with quite some distance by the Netherlands and Finland, whereas Austria disappears.

1.2. Only few companies

Though not listed in the Ernst and Young 2001 report, altogether, there are 48 companies engaged in the Austrian biotech sector but basically there are three big players and about 20 start ups.[1] The rest of the firms according to the Austrian classification count to the biotech sector but they produce e.g. beauty or healing creams, without doing basic or applied research.

Only few big pharmaceutical companies are present since the 1950s and 1970s. Boehringer Ingelheim (100 researchers cell cycle) and Baxter (who later bought up Immuno) settled down in the 1950s and Novartis (then Sandoz) in the 1970s. They chose Austria because there were many scientists easy to recruit, good tradition in bio-medicine and personal relations with then chancellor Kreisky, who made big efforts to attract multinational enterprises (MNEs). Austria's changing attitude towards MNE's (against MNEs in the 1960s, in favor of MNEs in the 70s, against MNEs till the 1990s, in favor since EU) is partly due to its historic experience as a defeated country under foreign occupancy, maintaining some xenophobic basic distrust, and partly due to some personal engagement of politicians, notably Kreisky in the 1970s, who wanted to copy the Swedish model of huge companies and later again Vranitzky/Klima who wanted to "Europeanize" Austria by attracting big foreign companies.

Similar to Austrian telecommunications, a predominant pattern of the Austrian biotech development is that there was more the hope to call in big companies from abroad than to take initiatives to develop spin-offs (Interview Gabain). Though biotech emerged out of spin-offs from universities, Austria has still too little SMEs that are research oriented, it lacks spin-offs and start ups (Interview Kuchler).

The three big Austrian biotech players: Novartis, IMP (the Institute for Molecular Pathology coming from Boehringer Ingelheim) and Baxter, produce in niches.

Novartis and Biochemie Kundl: Novartis, since 1970s (former Swiss Sandoz which merged with Cyba Geigy recently) , was built with foreign money with no Austrian banks involved and produces pharmaceuticals, with long product cycle, and with 200 researchers employed. Chancellor Kreisky had convinced his friends at the management of Sandoz to start activities in Vienna. The outcome was a mainly research oriented institute. The first years

[1]The Austrian biotech directory, edited by the Bureau for International Research and Technology Cooperation, the Innovation Agency and the Vienna Business Agency, has listed 62 companies. But some of them are only indirectly linked to biotech such as Zeiss optical products or Anton Paar, laboratory equipment and have a much wider field of activity.

Sandoz research had a very broad and open assignment. Now, after the merger with Cyba Geigy into Novartis its main activities are in genomics and human cell isotopes; search for disease genes involved in skin-cells; high throughput protein expression in yeast; but also, target identification, medical chemistry, and allergies. This multinational player took over the Austrian Biochemie Kundl in 1996.

The roots of Austrian biotechnology are in classical biotechnology. Austria has always been a prominent country in classical fermentation processes, especially brewing and wine making. Several historical examples show that Austrian companies can make rather radical changes from beer-production to medicine. After World War II the need for antibiotics was great and a Tyrolean Brewery group started the production of penicillin. Within a few years it managed to stabilise the product in such a way that it could be administered orally, which was a world patent. It was split off of the brewery group and has worked under the name Biochemie Kundl, until it was incorporated in Novartis in 1996. Building on this success, the production of antibiotics grew extensively and became an Austrian speciality.

Boehringer Ingelheim and IMP: Boehringer Ingelheim started its activities in 1948 in Austria, basically in fermentation processes. It started with a strong research-orientation and has kept that orientation ever since. The company's research and development efforts in Vienna are primarily focussed on oncology. Furthermore, it was one of the first European firms for the production of tumour vaccines. Intensive basic research in the field of carcino-genesis is being carried out in close cooperation with Boehringer Ingelheim's Research Institute for Molecular Pathology IMP. This very prestigious enterprise hosts one of the nobel prize winners in chemistry(?) of 2001.

Baxter: Baxter in Orth an der Donau is the largest Biotech company (600 researchers). It bought up Immuno, a former Austrian company. It produces a niche (plasma products, which are not considered a real biotech, vaccination, one recombinant product which is on its own worth 1.2 bill USD !). Immuno was a very early university spin off . In the 1950s Hans Eiber, still as a student made his first vaccine. Building on that successful innovation, Immuno AG was built. Next to its commercial success, it alway has kept a research oriented attitude. Immuno was until recently a private owned company (by a Swiss and a Brit), but the owners hardly cared about money. Profits were reinvested and used to build up a substantial research capacity. But this spin-off did not induce many other exmples.

In the early 1970s Austria seems to have had the gift to be an early bird but not to catch the worm. Some pioneer entrepreneurs do not seem to induce many followers. As was the case with Biochemie Kundl, the Austrian company (Immuno) was finally bought up by an international firm, Baxter.

Each of these companies has a research staff. Novartis (± 250 researchers), Baxter(formerly Immuno) (± 600 researchers) and Boehringer Ingelheim (± 200 researchers) are all private companies with a long standing history in basic and applied research. These firms have formed the core of the Austrian biotech industry.

It has taken long before startup activity has found solid ground. Most startups have started after 1996. It explains why most of the Austrian companies are rather small. 71% of all firms in biotech have less than 50 employees. The IHS (2000) survey shows that the majority of firms has between 5 and 20 employees[2]. In this category we find the majority of the Austrian start-ups. Some of these firms have a long-standing tradition in a specific field. Vogelbusch, for instance, is a well established firm, founded in the 1920 and mostly active in sugar, starch, pharmaceuticals, chemicals and food industry. Jungbunzlauer is another example, also active in the food and beverage industry, and especially known for its sweets and candies. However, many firms were only founded in the last ten years. Among them promising firms like Sanochemia Therapeutics, Quintiles and purely research oriented firms like Intercell, who develops synthetic vaccines can be found.

The structure of the Austrian biotech sector basically stands on two pillars. The first pillar are research activities of well-established firms in classical biotechnology, like breweries or in the production of citric acid and ethanol. These companies have been a jump board for activities in modern biotechnology. Their long-standing know how in fermentation processes facilitated the shift towards the application of new technologies. The second pillar is formed by small start-ups, as the spin-off activity of universities. Scientists with promising ideas have started their own firms, at increasing numbers after 1996, but several companies were found in the 1970s and 1980s. Some as a subsidiary of other firms (e.g. Novartis 1970), but others have concentrated on a specific niche in (contract) research, service or production (e.g. Nanosearch).

In Austria, the biotech innovation scene as an open book. *"Visit two or three conferences, and you know who is who and who is important in biotech!"* (Several interviews).

[2]The fact that it lists 4 representative firms from the sample, with more than 500 employees, can only be due to a much broader sector definition than ours. Because we come only up with 2 firms in the whole sector (see IHS 2000).

Overview Austrian Biotech Companies in 2001

	Firm	1-50	51-250	251-500	>500	R&D personel	starting year	export	service	R&D	sales	contract R&D	production	medicine	fine chem.	environment	food
1	*Amgen*	*1*				*n.a.*	*n.a.*				*1*			*1*			
2	*Amynon*	*1*				*n.a.*	*2000*			*1*				*1*			
3	*Aurora Feinchemie*	*1*				*5*	*1996*	*1*	*1*	*1*		*1*			*1*		
4	*Austrian Nordic*	*1*				*6*	*2000*			*1*		*1*		*1*			
5	*Axon Neuroscience*	*1*				*10*	*1999*			*1*				*1*			
6	*Baxter*				*1*	*500*	*n.a.*	*1*	*1*	*1*			*1*	*1*			
7	*BFE*	*1*				*n.a.*	*1998*	*1*		*1*		*1*				*1*	
8	*Bio gas*	*1*				*n.a.*	*1995*		*1*				*1*			*1*	
9	*Biolab*	*1*				*0*	*1983*		*1*		*1*			*1*			
10	*Biomedica*	*1*				*4*	*1978*	*1*		*1*	*1*		*1*	*1*			
11	*Biomin GTI*		*1*			*15*	*1983*	*1*	*1*	*1*	*1*		*1*				*1*
12	*Bio-Rad laboratories*	*1*				*0*	*n.a.*		*1*		*1*			*1*			
13	*Bio Tec Systems*	*1*					*1999*	*1*		*1*	*1*		*1*	*1*			
14	*BIRD-C*	*1*				*12*	*1998*		*1*	*1*		*1*		*1*			
15	*Boehringer Ingelheim*				*1*	*200*	*1948*	*1*		*1*	*1*		*1*	*1*			
16	*Byk Oesterreich*		*1*			*n.a.*	*n.a.*		*1*		*1*	*1*					
17	*Care Diagnostoca*	*1*				*5*	*n.a.*	*1*	*1*	*1*	*1*		*1*	*1*			
18	*Centeon Pharma*		*1*			*n.a.*	*n.a.*				*1*		*1*	*1*			
19	*Chemomedica*	*1*				*n.a.*	*n.a.*	*1*			*1*			*1*			
20	*Croma Pharma*	*1*				*5*	*n.a.*	*1*	*1*	*1*	*1*	*1*	*1*	*1*			
21	*GAT Formulation Chemistry*	*1*				*10*	*1997*	*1*	*1*	*1*		*1*	*1*		*1*		*1*
22	*Gruenenthal*	*1*				*n.a.*	*1977*		*1*	*1*	*1*			*1*			
23	*Haemosan*	*1*				*4*	*1988*	*1*	*1*	*1*		*1*		*1*			
24	*Ingeneon*	*1*				*8*	*1999*			*1*				*1*			
25	*Intercell*		*1*			*n.a.*	*1997*		*1*	*1*		*1*		*1*			
26	*JWS Research*	*1*				*n.a.*	*2000*			*1*		*1*		*1*			
27	*Jungbunzlauer*		*1*			*n.a.*	*n.a.*	*1*		*1*			*1*		*1*		*1*
28	*Labordiagnostika*	*1*				*4*	*n.a.*	*1*		*1*	*1*		*1*	*1*			
29	*MedSystems Diagnostics*	*1*				*3*	*1998*	*1*	*1*	*1*	*1*		*1*	*1*			
30	*Nanosearch Membrane*	*1*				*n.a.*	*1986*			*1*			*1*	*1*			
31	*Novartis forschungsinstitut*		*1*			*250*	*1970*			*1*				*1*			
32	*Nowicky Pharma*	*1*				*1*	*n.a.*			*1*	*1*	*1*	*1*	*1*			
33	*Oekopharm*		*1*			*16*	*1986*	*1*		*1*	*1*		*1*	*1*			*1*
34	*PE Biosystems*	*1*				*n.a.*	*1999*				*1*			*1*		*1*	*1*
35	*Pharm Analyt Lab*	*1*				*n.a.*	*1986*	*1*		*1*		*1*		*1*			
36	*Photo Dynamic Therapy*	*1*				*1*	*1994*	*1*	*1*	*1*	*1*	*1*	*1*	*1*			

37	*Pichem*	*1*				*5*	*1995*	*1*	*1*	*1*		*1*	*1*	*1*			
38	*ProCeryon Biosciences*	*1*				*n.a.*	*1999*	*1*	*1*	*1*	*1*		*1*	*1*			
39	*Quintiles*		*1*			*n.a.*	*1996*		*1*			*1*		*1*			
40	*Sanochemia Pharmazeutika*		*1*			*30*	*1992*	*1*	*1*	*1*	*1*		*1*	*1*			
41	*Schering Wien*		*1*			*n.a.*	*n.a.*		*1*	*1*	*1*			*1*			
42	*Serono Austria*	*1*				*5*	*1983*	*1*	*1*	*1*	*1*			*1*			
43	*Sy-Lab*	*1*				*6*	*1987*	*1*		*1*	*1*		*1*	*1*			*1*
44	*Torrex Pharma*	*1*				*2*	*1994*	*1*	*1*	*1*	*1*			*1*			
45	*TU-BioMed*		*1*			*n.a.*	*n.a.*			*1*				*1*			
46	*VBC Genomics*	*1*				*9*	*1999*	*1*	*1*	*1*	*1*	*1*	*1*	*1*			
47	*Vita Teq*	*1*				*10*	*2000*			*1*				*1*			
48	*Vogelbusch*		*1*			*2*	*1921*	*1*	*1*						*1*	*1*	*1*
	Total	***34***	***12***	***0***	***2***			***26***	***25***	***38***	***26***	***16***	***22***	***40***	***4***	***4***	***7***

Source: Oosterwijk et al (2001), Data provided by Company Directory, BIT, Innovationsagentur and VBA, 2001

2. The Specialization in Red Biotechnology

The Austrian system is almost exclusively oriented towards 'red' biotechnology. This distinguishes it from the Netherlands that engaged in all three fields, in particular in green biotech and from Germany that is also strong in environmental, grey biotech. Austria's biotech sector is most similar to the Finnish that also engages mainly in some niches of red biotechnology. About 70% of Austrian and Finnish firms engage in pharmaceuticals.[3]

One has to keep in mind that the Austrian pharmaceutical industry is small and its share in total employment is also lower than in the three other countries studied. Austria is a net-importer of pharmaceuticals and its industry consists mainly of small and medium sized firms and very few big players.

Several historical examples show that Austrian companies can make rather radical changes from beer-production to medicine (see Biochemie Kundl from beer to penicillin).

But the extreme Austrian specialization in red biotechnology was originally not to be expected and was the outcome of political rather than economic reasons.

The discussion about the application of gene-technology in Austria has started much later than in many other European countries, but the debate has been extremely fierce. It reached its

[3] The IHS (2000) survey estimates 62%. They sent the questionnaire to 87 companies, 57 responded, of which only 21 firms were active in modern biotechnology. Of these, 13 were active in bio-pharmaceuticals.

peak in 1997, in a "Volksbegehren" (petition), when more than 1.3 million of people protested against gen manipulated food. This petition had the second largest amount of signatures any Volksbegehren ever had in the Second Republic. As a consequence, plant releases were forbidden and no political party or interest association dared to touch this sensitive issue ever since. Politicians were hesitant to support or fund biotech. Today biotechnology is accepted in pharmaceuticals but not in food or environmental areas. Biotech has a bad image, it is "dirty" (Novartis).

2.1. The Historical Roots of the Petition Against Gene Manipulated Food

Austria had an early, quite well organized anti-nuclear movement in the late 1970s. In 1978, chancellor Kreisky put all his political weight on this issue. In order to avoid the environmental topic for the coming election campaign, he suggested a referendum on the power plant Zwentendorf. The plant was ready for use and the options the chancellor laid out were Zwentendorf in use or a resign of Kreisky. In the 1978 referendum the majority of Austrians rejected the civil use of nuclear energy. Austria was the only country that had a nuclear power plant that never was used. On the waves of the anti-nuclear movement, environmentalists also rejected large scale technological projects like the hydro-power station Hainburg. Many of the front-men and -women of environmental care movement were also the leading figures of the anti-gene-technology movement.

The need for an independent Austrian gene-policy started relatively late. The size of gene-technology research was remote and fragmented and insignificant from an industrial point of view. Austria did not have the big companies in 'green' biotechnology, which were planning field trials. Therefore, this line of research was rather inconspicuous. Surveys in 1991 and 1994 revealed a sceptic attitude towards technological development, even though government and political elites were strongly in favour of catching up with the neighbouring (West European) countries.

The discussions on gene-technology and reproduction technology in the late 1980s were strongly intertwined and had a strong ethical dimension. On the one hand gene-technology is a sensitive issue in the German speaking countries. "Eugenetica, euthanasia and selection: these words are connected with painful memories", according to Johannes Rau, recently in his Berlin Speech and in this context it goes without saying that the German regulatory structure has the Embryo Protection Law since 1991, which forbids research on embryos. A second ethical dimension, however, was more prominent in the discussion and this was the discussion about the acceptability of gene-technology in food-stuffs. However, it was a discussion without much public attention. Only few people participated in this polarised discussion, which has had a great impact on the process of decision making.

Following the German example, the Social Democrats (SPÖ) promoted the idea of a parliamentary inquiry commission to discuss gene-policy. Even though there were many different views in the committee, the final results were -by and large- unanimous and rather restrictive. The gene-policy debate was disturbing in the sense that the different views were not regulated by the traditional lines of social partnership. Parallel to the parliamentary inquiry a design for a bill was discussed and passed the Nationalrat even before the parliamentary inquiry commission had published its report (see Gottweis, 1997). Here we find the traditional lines: the Chancellor, the Ministry for environmental care, the Church and interest groups were in favour of a strict regime, while industry, research, science and the Ministry for Economic Affairs were opposed. In 1995 the bill came into force. The general characteristics of the law largely followed the EU regulatory structure.

This could have finished the discussion about gene-policy, if not some scandals had attracted much public attention. It is clear that the public opinion was rather sceptic against gene-technology, but the request for licences to perform some field trials has lead to a stream of indignation and opposition, especially when AgrEvo applied for a licence to plant herbicide resistant maize. Bio-farmers protested and demanded a gene-free zone, Kronenzeitung organised a petition and was even supported by the Minister of Agriculture and Styria.. AgrEvo decided to withdraw its request and the matter could have ended without losing face. However, at the peak of public turmoil, another project planted genetical-modified starch-potatoes, however, without a licence. The genetical modified potato that IFA in Tulln, the institute for applied biotechnology, had developed for starch production, for industrial purposes only, (Interview Herlitschka), became "the Frankenstein potato" in the public debate.. Austria who had wanted to establish itself as biological agro-food country was afraid of losing its image when just newly entering the EU in 1995 " (Grabner and Torgersen, 1998:216).

The impact of these scandals has had far reaching consequences. The development of an industrial 'green' biotechnology sector has completely stopped. No initiatives were taken from that moment. Research in 'green' biotechnology was only performed in the well - regulated environment of laboratories and laboratory greenhouses, but no applications for licences for field trials were made. Biotechnology became red.

3. Firms' Strategies in Red Biotech

3.1. Division of Labour: Centralisation of Research

The Austrian developments reflect the general tendency in the pharmaceutical industry. Companies like Baxter, Novartis and Boehringer Ingelheim are in a restructuring process. Big pharmaceutical companies like Baxter used to be divided into strategic business units, which were rather independent,with their own departments for science and R&D, marketing, regulatory, clinical and medical affairs, quality and legal affairs (especially intellectual property). Only recently this structure has been changed. Research was centralised, performing for all business units. This includes regulatory and clinical affairs, project management, portfolio management and process development (Interview Baxter). Size, scope and critical mass are getting more important.

In smaller startups, the idea innovation chain is rather short. Scientists work in close collaboration with production and many products are tailored to a specific demand. In startups, entities are still rather small. Several firms can count the staff number on one hand and only few have more than 50 employees. Cooperation among staff is high, particularly because staff-members have invested money in the company. Division of labour is rather created by project management or by technologies, than by the span of control. But since most of the star tups mainly concentrate on one specific technology, the degree of cooperation is very strong.

Research activities are centralised and concentrated around some major themes, while marketing and sales are decentralised. Novartis Austria's laboratory is the designated laboratory for all Novartis activities in the field of antibiotics, and the Novartis establishment at Kundl is the fermentation centre for the whole Novartis company worldwide. As so many companies, Novartis has actively stimulated the establishment of new laboratories to provide highly specialized services. Igeneon was established on the Novartis premises as a spin-off of the Novartis research group (compare Unilever and BAC in the Netherlands), and it has the chance to develop under the wings of Novartis, with participation of Novartis money.

The Institute of Molecular Pathology (IMP) is a special case. Whereas basic, applied research and product development as a rule are highly integrated in pharmaceuticals, the IMP was started as a basic research oriented laboratory. It had an independent status, but was initially owned by Boehringer Ingelheim and Genentech. After Genentech's withdrawal from this activity, Boehringer Ingelheim was the sole owner, but it continued its activities. The IMP has its own research agenda, but it also performs research activities for other parties, thus generating its own revenues. The IMP has organised its work in project-teams, each working on its own project for a limited period of time. This is an important feature, because (top) scientists are hired only on a temporary base. Thus overhead costs are low and flexibility is high. This enables the IMP to play a role in the top-segment of molecular pathology. Its high reputation is attractive for international scientists, and its high degree of mobility (by only hiring scientist on a temporary base) has resulted in a strong informal networks with outstanding research groups all over the world. As such, the IMP is rather a product of American culture than Austrian culture, with its tradition in long term labour contracts (see Oosterwijk et al 2001).

3.2. Spin-Offs and Management Buy Out

By international comparison, there are very few private or public institutes outside universities with real basic research in Austria. Basic research is done mainly at universities and the big companies (see IMP which is totally focused on basic research!). Applied research is mainly done by industry, by some management buy outs, and less so, by university spin-offs. Only today spin-offs do the whole idea innovation chain. VBC Genomics (DNA sequencing), started in 1992 at the university itself with own money. It developed allergy chips. Now there is a discussion with German banks for financing. It is the world leader for intellectual property but not leading in any markets. This example shows that selling knowledge can be as important as commercialisation . (Though one interviewee rather saw this as an indicator that Austria's major biotech characteristics are good ideas but bad commercializing).

Intercell (Prof. Gabain) is a very successful start up, at the Biocenter with 120 scientists, and develops synthetic vaccines, against cancer .

There are also some more spin-offs such as Nanosearch, but few by international comparison. There are also some few management buy outs. Medsystems Diagnostics (assays to monitor cancer) was founded by management buy out from Boehringer Ingelheim in 1998. This can be explained by the fact that the German headquarters of Boehringer decided to focus on pharma only and to sell all other business. Traditional pharma takes 10 years, Medsystems takes 3-6 months for a product. It therefore, has an extreme short term business cycle.

4. The Role of National Institutions

4.1. National or Regional? A City Initiative

Austria is strongly oriented towards its major trading partner Germany. Both for economic, geopolitical and historical reasons Austria's industry structure is more similar to the German than to the Netherlands or Finland. When the well funded and excellent advertised and marketed Munich cluster –BioRegio – started, the city of Vienna, under Social Democrat government, tried to follow this model two to three years later. The idea was to make Vienna not only a cultural center of music and tourism but to engage in high tech and to profit from its location to the East. (Before, some efforts by the Social Democrats to transform Vienna into a financial center in the late 1980s had failed). Also personal relations that are important for networks are easier when all are located at the same place.In biotech space is important. Contrary to telecom in biotech, in particular for SMEs, close location of enterprises is important. Costs for building are an important factor in the beginning of a biotech firm. Vienna was considered a good location due to history in medicine and closeness to the East.

It was especially city-councilor (Stadrat) Brigitte Ederer, who has actively promoted biotechnology as an interesting field for scientific and economical developments. She established the cluster-management for biotechnology and molecular medicine with the task to plan and coordinate future developments in the Vienna area to establish biotechnology clusters like those elsewhere in Europe and the United States. Its instruments are:

- the creation of laboratory space, including incubators for new spin-offs and startups at the Vienna Bio Centre. In addition it will try to establish efficient networking between biotech companies on campus and research groups at universities in order to create synergy;
- to attract new industries from countries with an already established biotech culture, for instance the USA, but also to attract companies and startups from the eastern European countries.
- to provide financial and logistic support for startup companies through funding resources of the Vienna Business Agency. Here the VBA works closely together with the Austrian Business Agency.

The nucleus of the Vienna Bio Centre is the Vienna University and Boehringer Ingelheim's Institute for Molecular Pathology. The founding of Intercell has marked the take-off of the biotech cluster and within a few years it has offered housing for entrepreneurial startup firms like Biomay, Axxon therapeutics, Medsystem diagnostics, VBC Genomics, Optin Therapeutics, and others. The establishment of the Vienna Biotech Centre has been the initiative of the city of Vienna and was mainly initiated by then city-councilor Brigitte Ederer. The Vienna Business Agency has been the executive organisation and its task was to develop and extend the Vienna biotech cluster. Currently the Vienna Bio Centre offers working space in one new building, but new buildings are under construction, meant to provide housing to the Austrian Academy of Science and several existing and startup companies in biotech.

The establishment of the Vienna Bio Centre has generated the discussion on how to develop the Vienna biotech cluster. Is localisation in one cluster a precondition for success, or is the current situation with laboratories spread over, or close to Vienna to be preferred.

The most likely scenario is the development of several smaller clusters in the close vicinity of universities (BOKU and the Veterinarian University) or of bigger research institutes. To give an example of the latter, Igeneon has developed as a spin-off of the Novartis Research Group. Distance in kilometers seems to be less important than (time) distance in public transportation.

The decision to form a cluster is a regional fact. But it is embedded in all kinds of national institutions. First, in public support at the national level, in a more or less coordinated technology policy, in a national education system., in law, in associational governance and in modes of finance.

4.2. The Chamber System

In Austria, every company is a compulsory member of the Economic Chamber, every worker belongs to the Chamber of Labour and every farmer to the Chamber of Agriculture. Furthermore, voluntary associations (business and trade unions) exist. This set of institutions forms "social partnership", the core Austrian associational economic governance system (see Hollingsworth/Boyer 1999)..

In the pharmaceutical industry, the Association of the Pharmaceutical Industry that comprises the big players such as Baxter, Novartis, IMP and Boehringer Ingelheim is very powerful and has certainly more lobbying capacity than associations which represent only small and medium sized firms. Nevertheless, also the association of the pharma industry has to play the game according to the Austrian rules. The country is small, the elite knows each others, informal networks are very important.

4.3. Education in Biotechnology

Supply of skilled personnel is in excess in Austria, at least in Vienna. 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 (4 - 5 years). The demand for skilled personnel thus has been low, while supply is more than sufficient. Here Vienna benefits from its well-developed education system. In 1996/97 about 3000 students finished their studies in biochemistry, biotechnology, botany, chemistry, nutrition sciences, genetics, human biology, food technology, medicine, microbiology, molecular biology, technical chemistry, veterinary medicine and zoology (Austria Innovativ, 2000)

It furthermore trains 200 PhDs every year in biotech related fields, while demand is much lower. Biotech startup activity is still in its infancy. Startups often start with small teams to get a business on its feet. After the initial phase and after having past the first milestones, a company can extend its personnel. However, this has 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. Large selection committees have to reach agreement over candidates and often these committees have more than 40 members: professors, assistant professors and students. It is no exception when chairs are vacant for several years. In this system only few positions are open each year. In fact, as a result, many Austrian scientist have to go abroad, because of lack of demand, and several of companies in Martinsried, Heidelberg or the USA have Austrian scientists in their highest ranks. (Interview VBA).

The level of the Austrian education system is well respected in international circles. Austria, especially Vienna, traditionally has a good reputation in bio-medicine and its General Hospital is not only one of the biggest in Europe, it also has a good reputation. Nevertheless, research as well as education, are rather fragmented. A close review of the system shows a high degree of specialization among university institutes, but some fields of biotechnology are missing. Austria is not an exception; the dynamics of biotech research and education are not the result of well designed systems, they are rather the result of specific pattern of specialism, fitting in an international environment.

Germany lacks bio-informatic students, is lower than OECD average in university education and low in international orientation of universities. Austria has similar traits but still produces an oversupply of biotech students for the very small Austrian biotech market. Investors mention the good education in biotech (Intervew Intercell). It has a brain drain to Germany and other countries. good university research and education but as is the case of Germany, a low share of academics. Biotech is a field with a lot of international researchers, many start ups have attended US universities. Reserach Companies have a lot of post docs as researchers. Novartis , e.g., since 1970s, with 200 researchers employed, extracts researchers from universities, Phds and post docs, from 35 nations. The Austrian problem is that the way back to university is almost impossible. Once a university spin off left, it cannot come back. This is just the opposite of Finland and the Netherlands, where back and forth going is possible. Austria relies rather on old fashioned strategies: universities do contractual research for firms.

There is a lack of strategic skills (strategic planning in the US much more elaborated, Harvard Business School etc). But in a global big organisation this is bought in (Baxter). But this is a handicap for SMEs.

Problems of low cooperation between academia and industry, though improving since the last four years (Interview Kuchler) will still continue for a while. Given the Austrian (and German) university system the way back to university from business will be difficult. Recruiting procedures take long at universities, publication lists of industrial managers are short.

4.4. Public Research Funding

Public funding of biotechnology concentrates on red biotech. 69% of all biotech funding was for bio-pharmaceutical research. However, there are no special bio-pharmaceutical programs.

The main characteristic of the Austrian public support system is that it is organized in an bottom-up way (see also Austrian telecommunications chapter). There is no large focused technology program for biotechnology at the federal level. As a result, the Austrian system of biotech research funding is rather fragmented. Biotech is not an exception; one can find this fragmented, bottom-up structure also in other scientific fields. An attempt to draw comprehensive top-down research programs is only undertaken in recent years, but the development of these programs is such that an evaluation of its strategic goals is premature. Biotechnology was funded with an annual average of 10 million Euro between 1994 and 1996, which is very little, about 0.4% of gross expenditures of R&D.

In public funding there are several ministries and funding organisations involved.
The Ministry for Science and Transport is mainly oriented towards the provision of basic research, coordination of EU research programmes and international R&D cooperation in Austria. The Ministry of Labour and Economic Affairs is active in the funding of applied research through research funds, and technology and innovation funds.

Public funding was executed within the traditional instruments of the research funding organisations. Two organisations have a crucial role in the Austrian funding system. First, there is the Austrian Science Fund (FWF), which is the main organisation for the promotion of basic research. The Industrial Research Promotion Fund (FFF) is the corresponding organisation for applied research. A third funding organisation relevant in the biotech field is the Federal Environment Agency (UBA), which is also active as a funding agency, but on a much smaller scale than the FFF and the FWF.

The principal goal of the FFF is to support innovation projects of the Austrian industry and to stimulate industry to increase its research budgets. The main characteristic of FFF funding is, again, a bottom-up approach. Industry is motivated to apply for projects. However, the selection criteria are structured in a way which aims to support innovative and high risk projects.

Indirectly involved in biotech is the Federal Environment Agency (UBA - Umweltbundesamt), who promotes studies on the ecological impact of biotechnology. The total budget for these activities has amounted to 0.4 mio Euro between 1994 and 1998.

Within the total budget of the FFF and FWF, biotechnology was not a very important element. Only 4% of FWF's 1998 research budget was devoted to biotech projects. In terms of projects the numbers were even lower. Only 30 projects (2%) were dealing with biotech related issues on a total of 1500 projects. In industrial research, funded by the FFF the situation was a little bit more favourable. On average 7.6% of all funds were devoted to biotech funds.

The table below summarizes the funding of biotechnology in Austria.

Funding Organisation	**All numbers in million ECU**		
	Total annual budget 1997	**Annual biotech budget**	**biotech budget 1994-98**
FFF (Industrial Research Promotion Fund)	136	6.94	34.7
FWF (Austrian Science Fund)	60	2.02	10.1
Ministry of Science and Transport	792	0.4	2
Chancellor's Office	4.55	0.36	1.79
Ministry of Agriculture and Forestry	38.98	0.33	1.67
UBA (Federal Environment Agency)	n.a.	0.08	0.41
Ministry of Economic Affairs	61.7	0.04	0.2

The public funding of biotech research is poor by international comparison. The national activities of the Innovation Agency were focused on the seed financing programme. Recently some initiatives have been started to increase research and technology transfer of biopharmaceutical research. The federal government founded and funded the Technologie Impulse Gesellschaft, which started the Impulsprogram biotech two years ago to help researchers to commercialize their patents through the founding of a start up company, but not much money was involved (Interview Hammerschmied). Some federal government programs, such as the Kplus program, aim at the creation of centers of competence by government in order to increase cooperation and collaboration. A center of competence is financed 35% by the federal government, 25% by the Land and 40% by the industry (see Interview Stiftinger).

But in biotech the major part of research is done by private firms. Already the history of Austrian biotech shows that major innovations developed out of traditional brewing companies. Austria's firms are small and medium sized and mainly in foreign ownership. Contrary to telecommunications, biotechnology private research had a strong basic orientation. Novartis (then Sandoz) had started its research labs in Austria with a very open and broad target. Only in the 1980s commercial, market-oriented targets were reinforced. Boehringers IMP was founded with the unique purpose to do basic research and still has this focus. Also Baxter puts emphasis on basic research. These big companies do research by either locating some R&D activities in Austria or by supporting start ups, by contracts with universities and by initiating spin-offs from universities. This latter strategy is still little developed. But it opens up new ways to escape the more and more restricted growth in university budgets . Start ups open up the opportunity to develop long term basic research programmes, beyond the limitation of traditional research funding through FFF and FWF.

Biotechnology relies strongly on private initiatives of few big companies and some academics. Weak public support is still listed as one of the major hindrances of biotechnology in the survey, the Institute for Advanced Studies (IHS 2000) did recently.

Austria's international participation in research projects is below EU average. Regarding the biotech related EU programs BIOMED 2, BIOTECH 2 and FAIR, the Netherlands -roughly- participated in one-third of all projects.. Austria has participated to a much smaller extent and participated in around 7% of the biotech projects. That is a relative low level of participation, especially compared to Finland, which participated in 10% of the projects (Oosterwijk et al 2001).

4.5. Finance

Austria's public funding focuses exclusively on the first part of the idea innovation chain, on ideas and first proof of concept. Public money concentrates on the financing of (public) universities and not on research institutes. In Austria there seems to be less public money involved than in Germany where 0.8 Euros public money adds to 1 Euro of private capital. In further parts of the idea innovation chain, investors are lacking money. Inventors must either have own money, find foreign investors or run out of money. There is a lack of public and private Austrian investors (Interview Baxter). And a disadvantage for small and medium sized firms who lack size for international financial markets.

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 Netherlands, and Finland 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 shows still its deep roots of very careful financing.

In Austria, nationalized banks had to provide some venture capital to some firms (Interview Baxter). 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 (Intercell). With EU membership increased competition among Austrian banks and privatization led to mergers etc, and changed this arrangement of nationalized banks. But 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.

Typical for the Austrian financial system is the lack of venture capital. Venture capital for biotech is largely dependent on stock market development. Fluctuations also affect investment for biotech. Developments on the public capital market also influence venture capitalists. Biotech has high starting 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 (Interview Kuchler, about enzymes).

The history of the Austrian bank based, risk adverse system with no huge private capital (this was missing after the war since Jewish big capital had been destroyed) led to the fact that big firms brought their money from abroad and small firms started with their own money or with the money from big companies.

Big firms such as Baxter and Novartis provide own research funds which help start up companies from their companies or elsewhere. (Interview Stuetz, Novartis). Spin-offs finance themselves with own money. VBC Genomics (DNA sequencing**),** started in 1992 at the university itself with the researchers' own money. Now they are in discussion with German banks for financing, but not with Austrian banks.

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.

The most striking feature is the lack of new financing instruments such as venture capital. In Austria there were only four venture capital disbursements in 1996, while Finland had more than one hundred, the Netherlands more than three hundred and Germany almost twelve hundred disbursements. The UK, France, Germany and the Netherlands together accounted for more than three-quarter of all European venture capital disbursed in 1996 (National Science Foundation, 1998).

Biotech startup often start with private personal money or family savings and loans, because banks have not been willing to provide loans to companies until they have reached the point where revenues equal the interest payments. Also the importance of business angels is rather remote in Austria, especially opposed to Finland and the Netherlands where business angels invests considerable sums each year ($ 750 million in Finland, the UK and the Netherlands (global technoscan, 2001). It is not so much that business angels are not willing to invest, but they hardly exist in Austria. 'In general, Austria is a very wealthy country, but it hardly has any real wealthy people; most of them have left the country in the 1930s and 40s', according to one of the interviewees.

5. Copying the German Model – The Vienna Biotech Cluster

The German Bioregio program started in 1995 and needed a lot of capital. According to some interviewees it had a very good marketing to make it known but not so much of a concept. In Austria one would need much longer decision process and more of a concept for this. (Interview Kuchler).

The Austria Bio Cluster was founded in Vienna in1998/99 by the city of Vienna. The amounts invested were much smaller than in Munich. "Two people are running the show in Austria, compared to 50-60 in Germany and it is slow going" (Kuchler).

Before, the promotion of biotech has not been a priority .E.g. the Vienna Business Agency promoting SMEs did not have biotech on its list since recently (Kuchler, Cluster Manager). The Bio Cluster gives infrastructure-space for large scale clinical projects. (6000 m2, later 12000 m2). These initiatives came from the city of Vienna, whereas the federal government did not support this very much. There is a lack of coordination between the two policy arenas, which is different from Germany.

The coordination of policy arenas is the more difficult in Austria, as universities and research policy is exclusively in the competence of the federal government, whereas technology policy is tried at a local level. In Germany, the universities are in the competence of the Laender, thus more congruent policy between research and technology policy is possible at both, the federal and the local level.

However, due to the smallness of the country, informations can be exchanged easier. There is an effort to coordinate the different governance levels in biotechnology: "Vienna is supporting innovation at the regional level and that quite considerably. The Innovation Agency is doing that at the national level and BIT, the bureau for international research and technology cooperation, is doing that with respect to the international interconnection. That was the idea behind.....Whenever you interview in this field, you will always meet the same 3 people...That is one of the differences compared to Germany. For instance we have lot of clients from Germany. They just tell us... could you please give me this information on financing on the European level. I am not able to find the right person in Germany. I am sent from Berlin to Bonn to Munich, but noone is able to give me this information. We in Austria have this rather centralized approach" (Interview Herlitschka)

However it is noticeable that there is a lack of intermediary institutions. Intermediary institutions such as Innovationsagentur are rare and deal only lately more intensively with biotech. Since 11 years there is a department for seed financing, today there are also Business Angels who help with know how, and third, they help with patenting.

There is also a lack of public research institutions outside the universities. Public research centers such as Seibersdorf cannot compete with the high funded German Fraunhofer Institute.

Compared to the German model, the political initiative to promote biotech by creating space and some funding and provision of know how was 1.) 2 years later, 2.) had less money, was at a smaller scale 3.) was without the huge federal government support which was the case in Germany. 4.) Austria does not have a concentration like the Max Planck Institute (of knowhow, money and locations). The Ludwig Boltzmann institutes cannot compete with it. The Austrian Biocenter (first established by IMP and some university institutes so as to facilitate contact) was built in silos instead of close cooperation (Interview Baxter). Austria hence lacks concentration and big finance. In Munich 60-70 companies and 2000-3000 employees are working, in Vienna there are 5-7 biotech companies (mainly start-ups), IMP and some university institutes with 200-300 employees (Interview Nanosearch).

The Biotech cluster enhances collaboration, e.g. Novartis with Intercell (Interview Novartis). But it cannot be compared in size and importance to Munich. Though some interviewees expressed some optimism that one day Vienna might catch up this seems still be a long road to follow and more like a vision than a fact.

Conclusion

Few big, centralised companies with strong positions in profitable niches have been the main players until the mid-1990s and the engine of Austria's biotech development..

Contrary to telecommunications, private research concentrated on basic research. Novartis (then Sandoz) started its laboratory with a very open and broad assignment and it was only in the course of the 1970 and 80s that research had to be more market-oriented. Boehringers IMP was founded as a basic research laboratory and it still is. Baxter (who bought up Immuno) also invested a lot in basic research and has always reinvested its profits to make such an approach possible. This might be one part of an explanation why Austria was so late in the development of startups

The Austrian have massively rejected gene-technology in a very successful 'Volksbegehren' (petition) in 1997 and Austria has developed a restrictive policy towards applications in 'green' and 'grey' biotechnology. Field releases were forbidden. The Austrian public opinion has continued to be very resistant to biotech applications and achievements in biotechnology were portrayed as dangerous scientific aberrations. In this climate scientists chose to have a low profile.

The general tenor of the Austrian interviews is that the pressure of the regulatory complex is rather mild, which can partly be explained from its position in the initial phases of the idea-innovation chain. Rules and regulations do not hamper research so much. Firms operate mainly in red biotechnology. If there would have been initiatives to do experiments outside the laboratories in the 'green' or 'grey' field the legal restrictions would have been felt much more as a hindrance. Yet, business in Austria has withdrawn from 'green' research. As a result, the pressure of the regulatory structure is not so much felt, because there is only limited research activity and no business activity, but measured against other countries, the pressure in 'green' and 'grey' is definitely severe.

In a European ranking of supportiveness of the business environment by SPRU (1997), Austria was the least supportive country for biotechnology. (Austria ranks top, Germany 6, Finland 7 and the Netherlands 13. Only Ireland and the UK are even more keen on biotech among the EU-15 countries)

Given these circumstances one might expect that the Austrian biotech community would reconcile in the fact that it is lagging behind in Europe, but that is not the case. *"Austria is pulsating with activities in biotechnology and biomedical research. Since the breakdown of the iron curtain and the entry of Austria into the EU more and more international life science companies are establishing branches in Austria. Additionally spin-offs and startup companies in the biomedical area are founded in increasing numbers. Being home to top-quality university research groups, as well as corporate research in bio-medicine and biotechnology Vienna is well prepared to spearhead and eventually lead these developments within Europe"* in the words of the cluster promoters Karl Kuchler and Sonja Hammerschmit in a recent country introduction in Nature Magazine (Nature 31-08-2000).

Until recently, financing was problematic. There was no venture capital fund active in the Austrian biotech sector. For Intercell, one of Austria's eye-catching biotech startups, there was no willingness to invest in this company, neither from banks, not from other financial institutions. An excellent knowledge base and reputation, private money, strategic alliances and participation from established pharmaceutical companies have provided the investments needed to start the firm.. The founding of the Vienna Bio Centre has been an important signal that has underlined the importance of biotechnology as a promising economic sector. The clustering of high reputation institutes (e.g. IMP and the Vienna University) with several startups at the Vienna Bohrgasse and the ambitious plans of the Vienna Business Agency to extend the Vienna Bio Centre with several buildings has been the trigger to bring together investors and start-up companies. The cluster initiators hope that the Biotech Centre will boost the development of new startups as well as the willingness of venture capital funds to invest in Austrian biotechnology. The establishment of intermediary organisations like for instance the Innovation Agency has created a new situation. Through the Innovation Agency startups and companies have access to a large international network of venture capital providers like Horizonte Management GmbH, Bank Austria, TFV High Tech Unternehmensbeteiligung GmbH, 3i Technologieholding, TVM Techno Venture Management GmbH, Global Life Science Ventures, etc.

With all these efforts going on in the Vienna biotechnology cluster, one would expect that Ernst and Young will take a closer look and reestablish Austrian biotechnology on the map in their report of 2002.

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Austrian	Interviewees	Biotechnology		
Name	**Organisation**	**Institut, Position**	**Adresse**	**PLZ**
Dr. Sonja Hammerschmid	Innovationsagentur		Taborstr. 10	1020
CEO Dr. Haas	Optin Therapeutics	CEO	Vienna Biocenter, Rennweg 95B	1030
Brian Salmons	Austrian Nordic	CEO	Veterinärplatz 1	1210
Fr. Stiftinger	Stadt Wien, ZIT, WWFF	Leiterin des ZIT	Ebendorferstr. 2	1010
Dr. Wolfgang Schallenberger	Nanosearch	CEO	Hettenkofergasse 13	1160
Dr: Michael Schaude	MedSystems Diagnostics	CEO	Vienna Biocenter, Rennweg 95B	1030
Dr. Peter Hanke	BioMey	CEO	Vienna Biocenter, Bohrgasse 7B	1030
Harald Isemann	TIG	Kplus	Grillparzerstr. 7	1010
DI Martin Cabadaj	Axon Neuroscience	CEO	Vienna Biocenter, Rennweg 95B	1030
Dr. Sabine Herlitschka	BIT	Biotechnology	Wiedner Hauptstr. 76	1040
Sascha Dennstedt	VBC Genomics	CEO	Vienna Biocenter, Rennweg 95B	1030
Prof. Herman Katinger	Polymun Scientific	CEO	Nussdorfer Lände 11	1190
Dr. Manfred Sippl	ProCeryon		Jakob Haringer Str. 3	5020 Salzbrg
Dr. Karl Kuchler	Wiener Wirtschaftsförde-rungsfonds	Cluster Manager	Ebendorferstr. 2	1010
Dr. Eberhard Pirich	Sanochemia Pharmazeutika	CEO	Boltzmanngasse 9a-11	1090
Prof. Alexander von Gabain	Intercell	CEO	Vienna Biocenter, Rennweg 95B	1030
Prof. Dr. Friedrich Dorner	Baxter	Head of R&D	Industriestr.	
Dr. Peter Stütz	Novartis	Vorstand	Brunner Str. 59	1235
Dr. Monika Henninger	Boehringer Ingelheim	Business	Boehringer Gasse 5-11	1121
Dr. Karl Wagner	Boehringer Ingelheim	Development	Boehringer Gasse 5-11	1121
Doz. Lukas Huber	IMP		Vienna Biocenter, Bohrgasse 7	1030

Interviews done by Herman Oosterwijk and Stefanie Rossak in 2001

ANNEX I B3. BIOTECH NETHERLANDS

Hesitant Entrepreneurship in the Dutch Biotech Industry
Sectoral Patterns of Development and the Role of Path-Dependency

Herman Oosterwijk

Utrecht University

Country Sector study as part of the final report of the TSER-Project ‘National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries’

Table of contents

1. Introduction

Bio-business is often regarded to be one of the few industrial sectors with a high growth potential. The number of bio-businesses worldwide has sharply increased in the last decades. Small startups have spun off from universities, research institutes and sometimes even from large enterprises. Enterprises with renown names in classical biotechnology have extended their scope towards modern biotech applications.

In the mid 1980's the Netherlands has been among the first European countries to develop a broad range of activities in modern biotechnology and for long it could be measured among the leading countries in Europe regarding its number of biotech startups (E&Y, various years). But despite its favourable position, it did not manage to sustain its position among the leaders. Other countries, especially Finland and Switzerland have surpassed the Netherlands in recent years, leaving the Netherlands on seventh place in a ranking of European countries. (E&Y, 2001).

What is the explanation for the decline? Is it a loss of interest among Dutch scientists to start a bio-business, is it rather a catching up of other countries, or is it perhaps the specialisation pattern of the Dutch biotech industry, with prominent places for applications in agriculture, food-processing, fine chemicals and environmental care next to applications in health-care and drug-development, whereas other countries have mainly focussed on the latter? In this report we will try to present the elements of an answer to these questions.

In this study we will focus on how economic and institutional actors have structured their mutual relations in research activities. We will use the concept of the idea-innovation chain to analyse how companies and knowledge institutes have organised research activities. This is the more interesting because the introduction of rDNA technology has provided scientists a new set of tools which enabled them to modify the genetic setup of an organism, and this has extended the biotech toolbox with an ever extending number of new tools: each representing a specialism and each differentiating the biotech field. We are especially interested in how actors along the idea-innovation chain coordinate their activities. Are these activities mainly coordinated within the hierarchy, or are they rather structured by market relations or network-like structures?

We will start this discussion with an outline of the organisational setup. We will argue that modern biotechnology has had a great reception, especially in the ‘green’ sector (agriculture and foods) and in the ‘grey’ sector (fine chemicals and environmental care), but seemingly far less attention in the ‘red’ sector (healthcare and drug development), because the economical importance of the latter sector is less important for the Dutch economy as a whole. We will furthermore outline how different types of economical actors have organised the setup of the idea-innovation chain. Subsequently we will examine how the institutional environment has influenced this setup and discuss the influence of funding systems, the labour market, education, regulation and government policies. We will finally end this report in a conclusion.

2. Historical roots in biotech research

The Netherlands has a tradition in the use of biotechnology, especially in agriculture, food-production and, more or less as an outsider- the chemical industry. In the postwar years an extensive programme of rationalisation, mechanisation and land consolidation has been implemented to increase overall productivity in agriculture. The *Dienst Landbouwkundig Onderzoek*[1] (DLO) of the Ministry of Agriculture, Nature Management and Fisheries has played pivotal role in this programme in that it had several research laboratories for almost any branch of agriculture (life stock, poultry, trees, flowers, bulbs, etc). The DLO research organisation was basically thematically organised and authoritative in each field. Much closer to the farmers and breeders was the system of *Landbouwkundig Praktijkonderzoek* (agricultural practical research). This organisation was structured in such a way that farmers and breeders could easily participate in its programmes and directly could benefit from its findings. The latter type of organisations had a much more local scope and reach and was well able to implement and monitor new technologies. In university research we find the Wageningen University of agriculture, with a more scientific orientation. This research structure has stood at the cradle of research in modern biotechnology.

An interesting feature is the interwovenness of the agricultural sector. Although only a small proportion of the population is active in agriculture, it is a most important economic cluster. In agriculture and the food industry we find a multitude of business-cooperatives, trading associations, agricultural boards, research institutes, banks and governmental polities, all closely interlinked and all moving into the same directions: increase of productivity and a good income for all actors in the cluster.

Small local cooperatives acted as trading cooperatives, and these have been very important for the diffusion of modern technologies, not only in the popularisation of artificial fertilizers, herbicides, fungicides and pesticides, but also in the diffusion of new methods, technologies and equipment. Larger cooperatives have been set up in the meat and diary industry. The latter industry has set up its own private research laboratory (NIZO), which had and still has close relations to Wageningen University.

The banking system in agriculture was based on the ideas of W.F. Raiffeisen, mayor at Heddesdorf (Germany), which had developed a decentralised system of inexpensive credit. These idea were implemented in a Raiffeisenbank for Protestant and a Boerenleenbank for Catholic farmers, which have merged in the 1960 in the RABO-bank.

The strength of the sector was further more increased by the existence of an influential Agricultural Board (Landbouwschap) and Commodity Boards (Produktschappen) for different lines of products, which

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[1] Governmental service for agricultural research

have acted like intermediary institutions between government and farmers. Politics, religion and profession were strongly linked in Christian Democrat movements, initially divided by religious communities, but later integrated in the CDA, which has been in power until the early 1990's.

Whereas all education fell under the responsibility of the Ministry of Education, Culture and Science, in agriculture we find the exception. All agricultural education was the responsibility of the ministry of Agriculture, Nature Management and Fisheries. Thus, the core of the agricultural sector was an example of interwovenness, with very close ties between the actors. Modernisation may have shaken the foundation of this close knit between the actors in agriculture, but the system of interaction was so much internalised that the remains of the system are still prevalent in today's agro/food cluster.

That the agriculture could develop into such an important sector was enhanced by physical and geographical conditions. The Netherlands has a range of different soils and water conditions, each allowing for special crops. The 'geest' with its sandy conditions just behind the dunes, provides an excellent biotope for cut-flowers and flower-bulbs. The northern lowlands for life stock-breeding and milk production, the polders for corn and beets, while the former moors provide an excellent basis for potato-breeding. Here we find also related industries, like flower auctions in the western part, diaries in Friesland, starch-production in Groningen, meat-production in West Braband. Yet, these favourable physical conditions could develop so prosperously because the Netherlands' strategic position in international shipping and logistics. High productivity in agriculture and a well developed infrastructure has provided the platform on which Dutch industry could build. Even though the Netherlands is not known as a very industry-oriented country, one can find extensive industries in food production.

The emergence of a well developed chemical industry is partly due to the strategically important geographical conditions, but there is another factor why the chemical sector could develop so prosperously. To cushion the loss of employment at the closing of the State-mines in the 1960's, a chemical cluster was build on the remains of the former State-mines. The Netherlands has developed special expertise in semi-finished chemical products and oil refinery. Both the food-industry and the chemical industry have made extensive use of classical bio-technological fermentation processes.

Thus, in the mid 1970's we find three important economic sectors, that could prosper so much from developments in biotechnology: agriculture, the food-industry and the chemical industry. In chemicals we find AKZO and DSM in bulk-chemicals. On the interface between food and chemicals we find Gist/Brocades and several smaller pharmaceutical companies. On the interface between agriculture and chemicals we find AVEBE, one of the leading European companies in starch production.

As mentioned before, as soon as technologies rendered available to modify the gene-structure, it has opened doors towards new applications. In general one can say that two directions in research have especially been important in biotech: 1) the application of the modern biotech tools in R&D and production, and 2) the unravelling of the genome-structure of several species, among them the human genome. The Netherlands have especially invested in the first line of activities, the application of biotech tools in R&D and production, or in a broader sense, the application of biotech in agriculture and industry. For the second line in research the Royal Dutch Academy of Science has concluded that the Dutch participation in important international projects, like for instance the Human Genome projects has been disproportional low, which has resulted in a lack of stimuli to invest in research on the relations between sequence and structure, function or other forms of post-genome research (KNAW, 1999, p.57). Nevertheless, the Association of Dutch Universities has concluded that, despite its relative small scale, Dutch bio-medical research in general has a satisfactory scientific level, in some field even belonging to the best in Europe, especially in oncology and immunology (VSNU, 1998).

3. Measuring size and strength of the biotechnology in the Netherlands

3.1. Number of firms

Biotechnology in the Netherlands has had a good start in the 1980's, but did not manage to keep pace in the 1990's, regarding the number of startups. Especially these last few years, the Netherlands has lost its once prominent place in the ranking of countries. In 1997 it was listed behind the UK, Germany, France and Sweden in Ernst & Young’s monitor of ELISCOs. In 1999 it was surpassed by Switzerland and in 2001 also by Finland (Ernst & Young, 1997-2001)

However, in Ernst & Yong’s analysis, only life science firms with a strong entrepreneurial attitude are listed. That is why there is a difference between the data provided by Ernst and Young, the Dutch Organisation for Applied Scientific Research, the biotech associations or others. It is, however, fair to assume that around 90 companies are actively involved in biotech, of which 70 are identified as ELISCOs (according to Niaba/Biopartner and Ernst & Young). In appendix III we have listed the main players in Dutch biotechnology, whether they are firms, consultancies, graduate schools or research institutes

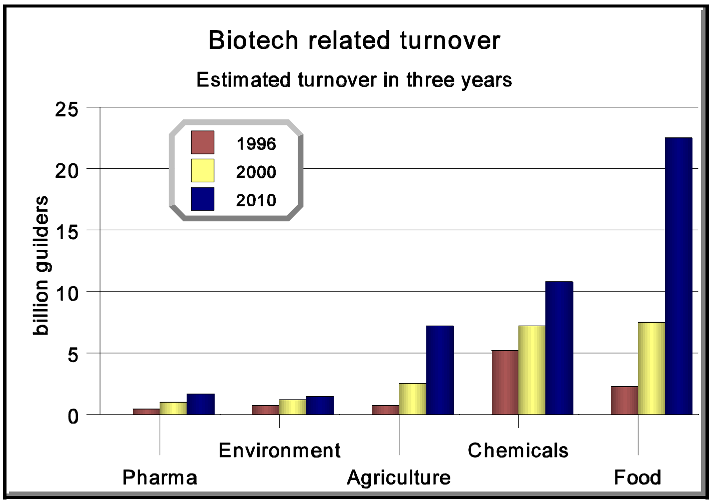
3.2. Turnover by sub-sector

A clear-cut classification of the Dutch biotech sector is hard to give, because there is considerable overlap between fields. Knowledge of plant-breeding can be applied in agriculture, but also in pharmaceutical or even chemical industry. Even though each classification system has its flaws, we will start this section with an impression of the economic importance of five relevant sectors, as they are listed by Degenaars and Janszen (1996). The food-industry is the biggest sector with an annual turnover of 75 billion guilders in 1995, which is practically the same as the joint turnover of the chemical industry (40 billion guilders) and agriculture (36 billion guilders). These three sectors are the leading economic sectors in the Dutch economic landscape in the mid 1990's. Compared to these giant sectors the contribution of the environmental care sector (8 billion guilders) and the pharmaceutical sector (4.9 billion guilders) is just modest. In the Degenaars/Janszen report experts have tried to estimate the share of turnover in the above mentioned sector that was related to biotechnology. First they estimated the biotech related part in 1996, but they also made predictions for the year 2000 and 2010. Just for the sake of argument we made an extrapolation, based on the 1995 figures, to demonstrate the economic strength of biotech related turnover as it was perceived in 1996.

In 1996 the share of biotech related turnover was highest in the chemical industry (13%) and the economic impact at that time amounted slightly more than 5 billion guilders. The biotech related share in pharmaceuticals and environmental care was also high (9%), but the economic impact was relatively modest. The biotech share in agriculture (2%) and the food-industry (3%) was low, but the economic impact was comparable with pharma and environmental care in agriculture or was even stronger, as is the case for the food-industry.

By 2010 the landscape was thought to have changed considerably, with an increasing importance for biotech related turnover. The environmental care sector was thought to have the lowest share (18%); the food-industry and the pharmaceutical industry the highest shares (resp. 30 and 34%), the agrarian sector and the chemical sector with share in-between (resp. 20 and 27%).

An extrapolation like this has excluded dynamism within each sector, but still it clearly demonstrates the line of thinking in the mid 1990's. The economic potential was thought to be



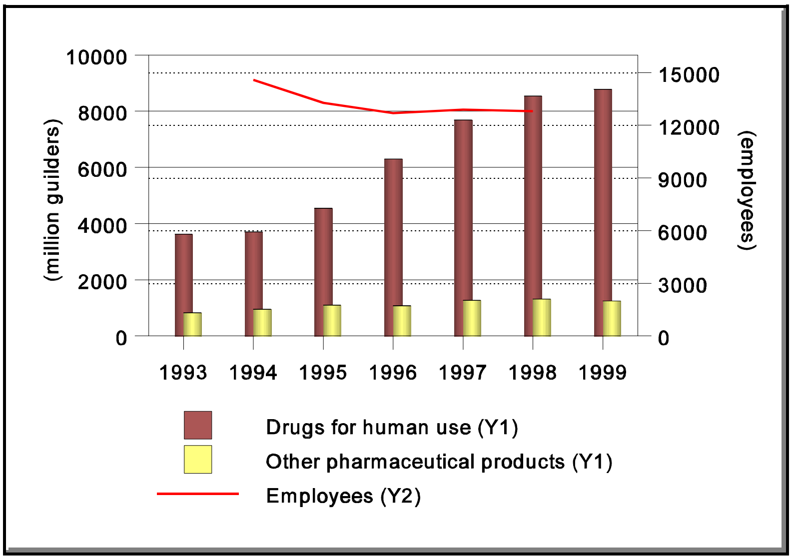
Afbeelding 1 *Expert opinions of biotech related turnover in three years, based on a projection of 1995 turnover in five sectors.*
Calculations based on data provided by Degenaars and Janszen, 1996

most impressive in agriculture, the chemical industry and especially the food-industry, and relatively modest in the pharmaceutical industry and environmental care.

Nowadays we find almost 40% of Dutch biotech firms active in human or animal healthcare (Holland Biotechnology, 1999), for the bigger part in the development of platform technologies, like sequence-analysis, vaccine and diagnostics, or special ingredients for pharmaceutical use. The biggest player is AZO-Nobel, with its subsidiaries Organon, Organon Technica, Diosynth and Intervet, and Solvay Pharmaceuticals. Crucell (until recently Introgene and U-BISYS) and Pharming are two of bigger independent players in the Dutch biotech field. Crucell is mainly involved in gene-therapy and Pharming is developing novel drugs for the treatment of Pompe's disease. However, contrary to AKZO Nobel, most of the Dutch companies in pharmaceutical research are small and medium sized enterprises.

Several multinationals have subsidiaries in the Netherlands. Often these are mainly involved in production and distribution, but some of them are actively involved in biotech research, like for instance Yamanouchi, which took over the pharmaceutical branch of the Former Gist/Brocades

The Netherlands is just a modest player in the international pharmaceutical sector. (Ministry EZ/TNO, 2001). The Dutch pharmaceutical industry had an annual turnover of approximately 10 billion guilders and offers employment to 12.800 people in 1998. None of the Dutch pharmaceutical companies is among the world's top ten players in human healthcare.



Afbeelding 2 *Sales of Pharmaceutical production 1993 - 1999*
Source: CBS

A different situation is to be found in animal healthcare. Here we find AKZO Nobel's veterinary branch Intervet as one of the leading companies (third after Merial and Pfizer). The origine of the specialisation pattern in the Dutch pharmaceutical industry can thus be traced back to the economic importance of the agriculture and food-cluster; in short: the 'green'sector.

In plant-refinement and seeds there are approximately thirty companies active in biotech (research)

(Ministry EZ/TNO, 2001). Among them ten companies, which are now part of the large world players like Novartis, AstraZeneca, Syngenta Mogen, Seminis Inc. and others. These big players are strongly involved in research. The smaller, independent companies have often out-sourced research activities to university groups or other research laboratories.

. Dutch companies like Barenburg and Cebeco, and UK/NL companies like Advanta are listed among the world leaders in seeds (IMBA, 2001). AVEBE is a world leader in starch-productions and the Netherlands has a good reputation in the cut-flower industry. However, research in plant refinery has experienced a serious set-back by a change of regulation. Many strains of research have been based on the use antibiotic-resistant genes. From 1999 on, only a few genes (nptII and hpt) are allowed in research, thus ruling out important strains of research that have been develop in the past and which were close to market-introduction. This measure has had a severe impact; the starch industry was on the verge of a large-scale field trail and already had invested millions in this project. The flower industry has turned its back to risky research and also the seed industry has shelved research.

This measure has made companies shy to develop new strains of research, especially because genetical modification is high on the public agenda again. Public debate has forced companies to take a conservative stance towards the application of modern biotechnology in agriculture as well as in foods. Thus, the early successes in biotech research has been set back by a strengthening of the regulatory regime and public resistance against genetically modified food-ingredients.

Dutch firms also have a prominent position in the field of environmental care (Ministry EZ/TNO, 2001). Companies like Pacques, Biothane, Bioclear, Cleartech, Bioway, Biosoil, Biostar and BRCC have an excellent international reputation. That is also the case for consultants in this field. The market for environmental care activities is approximately 10 billion guilders and 20% of that market is targeted with biotechnology (Ministry of EZ, 2001). 75% of the market for environmental care consists of equipment, large systems and machinery, and related services. The other 25% consists of specialized services, like management, environmental consultancy and bio-technological services. The strength and development of the market for environmental care is largely the result of rules and regulations and the Netherlands have been a frontrunner in the design of the regulatory system in this field.

3.3. Localisation of firms

Biotech firms in the Netherlands are usually to be found in places with a University. Of all biotech firms founded after 1990 only 12 were established in places without a university. Lelystad is an exceptional case, because it does not have a university, but an important research institute (DLO-ID), which is now integrated in the Wageningen University and Research Centre. Groningen has the most startups (12) and has developed an active policy in this respect. Leiden, although rather small as a city, has 11 startups within its city limits. Amsterdam, as Leiden concentrating on general biotechnology and medical care, has eight companies. Utrecht, Wageningen and Nijmegen each have 7 companies, Delft 5 and Maastricht, which is one of the youngest universities, has three startups. Thus, biotech research is more or less scattered all over the country, giving each university room to develop its own strain of research.

3.4. Division of labour along the idea-innovation chain

Firms differ in size, scope, history and reach. That makes whatever what comparison tricky, because what sense does it make to compare an old, established firm with a young startup company? Counting firms is, thus, is not the best way to get a good impression of the organisational setup along the idea-innovation chain. We will therefor typify companies and explain how they cooperate along the idea innovation chain.

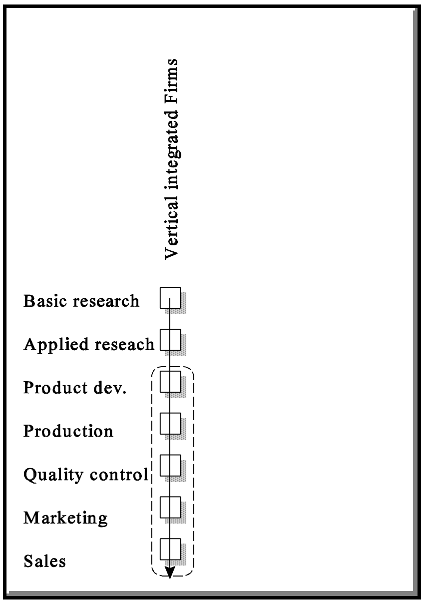
Vertically integrated firms

The classical vertical integrated firm is especially to be found in the pharmaceutical industry, the food industry and the chemical industry [2]. These, usually well-established firms have have taken up the challenge of using the new tools provided by the biotech toolbox and have set up special programmes in biotech research.

Although the characteristics of these new tools may have differed from the classical tools, the setup of the idea-innovation chain was not altered. It was basically a linear approach in which novelty stemmed from basic research which was steps-wise guided through applied research, product development, quality

[2] Examples: Unilever, AKZO Nobel, DSM, AVEBE, Nutricia, Campina, Advanta

control, marketing and sales. However, there are certain differences. Each new product of the pharmaceutical industry has to pass a highly sophisticated and standardised procedure, before it is admitted onto the market. The procedures are such that no variation is allowed that could jeopardise the results of that procedure. In practice, the first three phases are often closely interwoven, but the downstream steps are basically defined by legal admission procedures, which may take several years. Also the food-industry has to pass admission procedures, but these are not so detailed and standardised as for the pharmaceutical industry. Especially in the food-industry one can easily follow the upstream phases of the research process, but as soon as a project reached the stage of product development it can easily flare out to a range of products and brands, each with its own dynamics. Thus, the downstream phases of the idea-innovation chain may be managed as highly integrated networks.



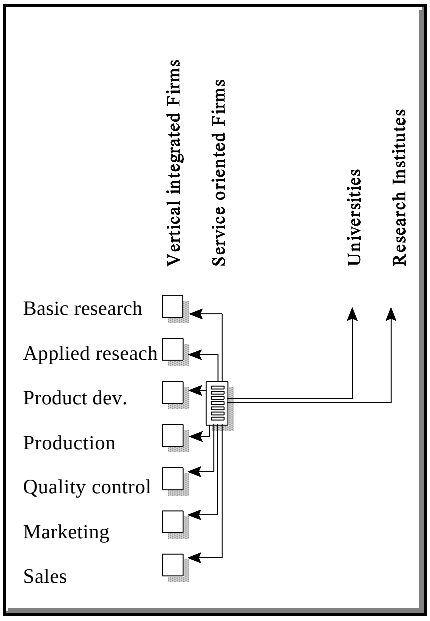
Afbeelding 3 *Vertical integrated firms along the idea innovation chain*
Arrows: market relations
Dotted rectangles: networks

Service oriented firms

The service oriented firm is the provider of a specialist service or product to other firms, active along the idea innovation chain [3]. The service or products can be provided to any phase of the idea-innovation chain, however, most often in the field of basic or applied research. Diagnostic kits for instance can be in the phase of production and quality control. These kits are often much more efficient, and often more reliable than the classical kits and procedures. These kits are widely used for instance in slaughter-houses, creameries and other firms in the food-industry. So the graph opposite is misleading in the sense that the service oriented firm is not particularly oriented to one specific phase of the idea innovation chain. A

[3] Examples: Cellscreen, Baseclear, Bio-Rad laboratories, Dyax Target Quest, Keygene, Kreatech, etc.

special kind of service oriented firm can be found in bio-informatics. These companies identify substances, classify them an put the results in huge databases. This is extremely valuable information for other companies along the idea innovation chain.



Afbeelding 4 *Service oriented firms along the idea innovation chain*

Within each service oriented firm one can identify all the steps of the idea innovation chain. These companies have to upgrade their service constantly to be attractive for their customer. In that they communicate what type of service the customer demands and if changes are taking place. If necessary they adjust their service to new demand. However, the drive to keep the service state of the art is rather originating from scientific and technological developments in their specific field of service, than from customer demand. The relations between service oriented firms and their customers are usually regulated by the market and knowledge transfer is thus relatively limited.

Entrepreneurial firms

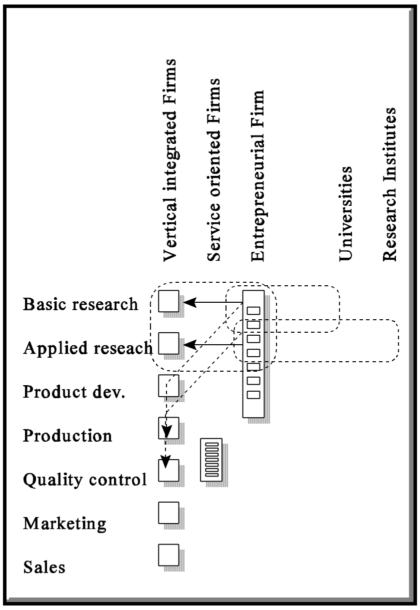
The entrepreneurial firm has the greatest appeal in life science [4]. Ernst & Young have build their series of annual trend-reports around the ELISCO, the Entrepreneurial Life-Science Company, and in the comparison of a country's performance, the ELISCO is the major indicator. Indeed, the entrepreneurial life science company is the most appealing in that it uses high-risk strategies, with the prospect of massive gains. The dark side is that success can easily collapse as we could recently have observed in the bankruptcy of the Pharming-group, until recently the one of the flag-ships in Dutch biotechnology. In sight of market-introduction this company has lost confidence of shareholders and it is most likely that most of

[4] Examples: Crucell, Pharming Group, Pepscan in pharmaceuticals, Aventis, Novartis, Syngenta Mogen in Agriculture

the company will be sold to one of its competitors.

The main asset of an entrepreneurial firm is its knowledge. This type of companies are especially to be found in the pharmaceutical industry and is extremely research oriented.

The archetype of an entrepreneurial company is active in drug-development. Its strategy is to develop a new drug for a specific disease, or a group of diseases. The research process usually starts with screening processes to identify active substances to fight that specific disease. In pre-clinical research the substance is tested in animals and basically all the properties of the final product are present as the product starts the procedure to get market-admission. This is a four step procedure to test the effectiveness, efficiency, reliability and safety of the product in humans. This procedure is time and money-consuming and it is partly for that reason that entrepreneurial firms step into strategic alliances[5] with large, capital-rich companies to finance the whole trajectory. It is no exception when the entrepreneurial firm sooner or later is integrated in these larger companies; the dotted arrows point in that direction. However, other reasons, like cooperation in research and share tacit knowledge in the exchange of scientists are often as important as financial reasons.



Afbeelding 5 *Entrepreneurial firms along the idea innovation chain*

Thus, most entrepreneurial firms are initially just loss-making firms. The pure form of an entrepreneurial firms is only seldom found. Usually these firms are a mixture of an entrepreneurial firm with service oriented firm to generate revenues to finance at least a part of their research efforts, these firms patent their technology and licence it to other companies. These are basically market-transactions, although considerable knowledge is transferred in these transactions.

As discussed before, entrepreneurial firms are usually closely integrated in network-like structures with large vertical-integrated firms, for instance in strategic alliances or joint ventures. They often have close contacts with universities or research institutes.

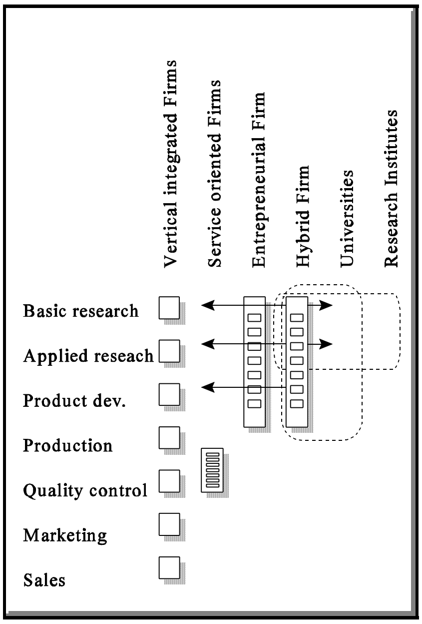
Again, like in the service-oriented firm, one can identify the steps of the idea-innovation chain in these

[5] Crucell for instance makes its technology available under exclusive and non-exclusive licence agreements and has currently signed 16 agreements with major pharmaceutical and biotechnology companies for its PER.C6™ technology, such as Merck & Co. Inc., Pfizer/Warner-Lambert, GlaxoSmithKline, Novartis, Aventis, Schering AG, Genzyme, Enzon, Cobra Therapeutics, Oxford BioMedica, Bioheart, DirectGene, EuroGene, Cellgenesys. It has signed and exclusive agreement with Merck & Co, under which is was granted a licence to use Crucell's PER.C6™ platform to develop vaccines for the prevention and treatment of HIV. In functional genomics Crucell has invested through its joint venture with Belgian based Tibotec, called Galapagos Genomics

companies, albeit that these steps are usually highly integrated. The reason is that research results are the most important assets of these firms; production, market- admission, marketing and sales are usually done in close combination with vertically integrated firms.

Hybrid firms

The last type of firm is the hybrid firm. This type of firm has the characteristics of a private firm, but the dynamism of a knowledge institution. This firm is to be found at universities and research institutes, especially when knowledge comes available that is attractive to be commercialised, or when knowledge is developed that does not fit in the structure and funding systems of both institutes. These hybrid organisations are especially involved in basic research, but also in applied research and product development. Some of these hybrid organisations develop under the wings of knowledge institutes even though they have the characteristics of a service oriented company. The dominant type of management and outside orientation is, however, provided by the institutional culture of the knowledge institutes. Often these firms cooperate with university research groups a one operational unit. They attend the same meetings and use the same coffee-machine. The knowledge-flow to and from hybrid organisations is usually very open and bears the same characteristics as of university research groups. However, knowledge does not flow so easily between these organisations and their customers. Here they have the same characteristics as service oriented companies.

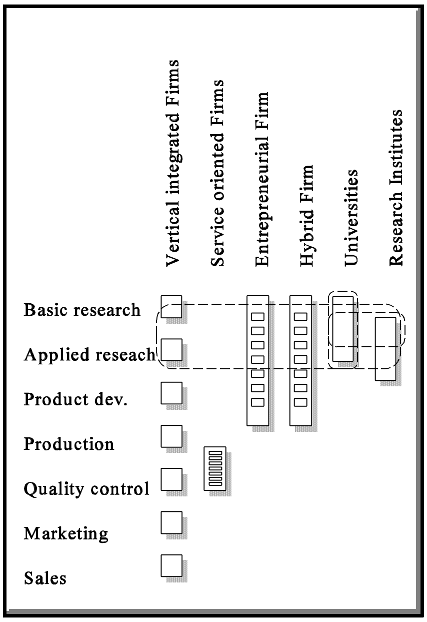


Afbeelding 6 *Hybrid firms along the idea-innovation chain*

Indeed, some hybrid organisations develop into service oriented companies, when they have proven to be able to stand on their own feet. A development towards a entrepreneurial firm, and high risk strategies is less likely to happen. For that the hybrid organisation seems to lack the real entrepreneurial spirit

Universities and research institutes

Knowledge institutes like universities and (public or private) research institutes have already been discussed in the above, but some relevant aspects have not been touched yet. By and large one can say that the universities are mainly active in basic research with some links to applied research, while research institutes are mainly involved in applied research with (numerous) links to basic research. The knowledge institutions are basically dominated by an open flow of knowledge. Education is only one of the means to transfer knowledge. Scientific papers, publications, demonstrators and prototypes are as important. The knowledge-institutes are rather dominated by network-like structures than by market-relations. 'Selling knowledge' was until recently considered 'not done'. However, the tide is turning; commercialisation of knowledge is under construction and the hybrid institutions are a good example of that tendency.



Afbeelding 7 *Knowledge institutes along the idea-innovation chain*

At universities one can observe two tendencies; on the one hand there is the tendency to excel in a specific field of knowledge and thus to shelter the field from outside interference. On the other hand there is the tendency to cooperate and build knowledge networks. The latter tendency is especially visible in the system of graduate schools, where universities cooperate in research and the education of PhD's. In some of these graduate schools one can also find the collaboration of research institutes and sometimes even the research laboratories of the large vertical integrated companies.

Associations

The most relevant association for the Dutch biotech sector is Niaba which used to be the acronym of the Netherlands Industrial and Agrarian Biotechnology Association, but it recently changed into Dutch Biotechnology Association, because the name was too often solely linked to agrarian biotech. Historically it has been involved in all fields of application and is especially aiming at giving proper information about the application of biotechnology, even though Niaba might possibly be a *'suspicious organisation'* in the eyes of its opponents. In its view, the public has been confronted with a lot of nonsense regarding biotechnology and in fact it is of the opinion that universities and research institutes have to play a role in this field. Communication, information and public awareness is one branch of activities; the other is the education of (potential) entrepreneurs in the Biotech Masterclass. In this programme several organisations and institutes cooperate to educate entrepreneurs on the peculiarities of life-science entrepreneurship. An important side effect is that these activities help to constitute informal networks.

Nefarma used to be the traditional association for the pharmaceutical industry. However, in the eyes of several Dutch biotech firms, Nefarma is too much the mouthpiece of the chemical pharmaceutical industry, and not able to communicate biotech developments with the relevant authorities, like for instance ministries. As a reaction BioFarmind was founded. The association BioFarmind has members in small and medium sized pharmaceutical firms, mainly active in biotech drugs (sales, production and research). BioFarmind's main aim is to stimulate the Ministry of Public Health, Social Welfare and Sports to take action in the sense of rules and regulations. The present rules and regulations are based on the paradigm of the 'old' chemical industry and do not apply for biotech medicine.

Niaba regrets the existence of more associations because it is a fragmentation of powers and it leaves politics the opportunity to rule and divide. From a strategic point of view it has criticised the pharmaceutical industry, because the detachment of pharmaceutical biotechnology from other applications leaves the others fields much more vulnerable, which also may backfire on the pharmaceuticals sector. Furthermore, fragmentation dilutes the effectiveness of lobby-work. Niaba has an entrance in many ministries, but so have the other associations and this is regarded a weakness, because ministries are regarded to be the masters in the game of rule and divide.

3.5. Research structure in university research

It is hard to outline a general research structure in biotechnology, because most of the fields of application are interrelated and have a substantial overlap.

- The research structure in *health related fields* fully or partly covers scientific fields as for instance immunology, pharmacology, micro-biology, bio-chemistry, genetics, cytology, virology, clinical chemistry, bio-physics, medical physics, histology, etc. The Netherlands has a sizable and broad knowledge base in medical biotechnology, which by international experts is labelled as 'satisfactory' to 'good', but biomedical research is rather fragmented (VSNU, 1998, EZ/TNO, 1999).
- The research structure in *plant biotech* is mainly concentrated at Wageningen University and Research Centre, but several other universities are also involved in plant research, albeit in the context of drug development (universities of Amsterdam, Groningen and Leiden) or in the context of health related fields or environmental care (Universities of Leiden and Delft). Research in plant technology is an extensive field and has a high reputation in the international field. Wageningen University has an excellent reputation in the agricultural field. Its graduate school Plant Research International has developed DNA chip-technology, together with a research group at RIKILT. The

same groups have founded the Gene Detection and Expression Centre. Greenomics, a newly founded laboratory which has four ultra high throughput sequencers. This concentration of research capacity has given Dutch plant research an outstanding position next to its German and French counterparts (EZ/TNO, 1999).

Research in the plant sector has tight connections with industry and aims at analysis of genes in important species of plants like wheat, rice and colza. Peer review has qualified the scientific level of Dutch plant research and its practicability in industry as very high (Benedictus and Enzing, 1998).

- Research in *animal biotech* has concentrated in two networks. The Utrecht University network mainly concentrates on gene-expression in animals and developmental biology. The veterinary and biological faculties, and the Hubrechts Laboratory are the main participants in the Utrecht network. The Wageningen network mainly concentrates on reproduction technologies, marker assisted breeding and contributions in the unravelling of the genome of rural home animals. It is organised in the Wageningen Institute for Animal Sciences and the former Institute of Animal Health and Zoology, now part of Wageningen University and Research Centre. On average, the quality of research is good, but rather fragmented. The Wageningen network for instance has a good reputation, but this is especially for its applicability. It has lost ground in fundamental research. The Utrecht veterinary network has a passable reputation, but it needs improvement. The activities of the Hubrechts Laboratory, which concentrate on fundamental biological research are not well integrated in the veterinary network. The Netherlands is in danger to lag behind in international developments in animal biotech. The main reason for this is the reach of the public debate on biotechnology. The public debate has concentrated in two fields: the desirability of modern, genetic, techniques in food (often adressed as Frankenstein-food) and the ethical discussion; is everything that is possible also desirable or even acceptable. Both discussion have an overlap, but a different character. On the whole, the discussion has hampered innovativeness (EZ/TNO, 1999).
- Research in *food biotech* has a long standing tradition in fields with a significant economic importance for the Dutch industry, like yeast, lactic acid, bacteria and fungus. The core of food research is concentrated in two important research networks. First the graduate school Food, Food-Technology Agro-Biotechnology and Health (VLAG) in which a range of universities and research institutes participate (see appendix I). The second network is the Wageningen Centre for Food Sciences (WCFS). The level of scientific research in this field is excellent, not in the least because of its close cooperation with and participation of big industries in several research projects and graduate schools. However, it does not cover the full range of activities needed in biotech research. The Netherlands for instance do not have a renown position in bio-informatics. Even though the Dutch presence in the international scientific field is impressive, it lacks the presence of a cluster of

important research groups, startups and innovative companies, as is to be found in Cambridge or certain US regions like Boston (Chemical Weekly, 1999, EZ/TNO, 1999).

- Research in *bio-technological chemistry* is divided along several lines of research The Delft University for Technology and Groningen Bio-molecular Science and Biotechnology Institute are concentrating on the use of enzymes as biocatalysts. The contribution of modern biotechnology is the optimisation of their activity by genetic and protein engineering. Wageningen University and Research Centre, especially Plant Research International and DLO/ATO are known for their research using plant cells as biocatalysts. Amsterdam Bio Centre and Nijmegen University are also active in research in biocatalysts. Furthermore, Eindhoven Technical University participates in a special programme aiming at the development of 'green routes' in semi-synthetic antibiotics (EZ/TNO, 1999).
- Research in *environmental biotech*, especially concerning basic research is performed at the universities of Delft, Eindhoven, Wageningen and Groningen. However, many other actors like research institutes, large industries, consultancies and local authorities are involved in this type of research. The size and scope, but also the funding structure of environmental projects is such that this field should be studied on a rather case-to-case basis. The Dutch performance in this field is excellent, mainly induced by two factors. First the Netherlands has been among the first countries to introduce high standards regarding environmental care and second, it has stimulated research and science/industry cooperation by financial incentives (EZ/TNO, 1999).

It is fairly impossible to make a sharp distinction between the different fields of biotech involvement. For instance, eight of the thirteen Dutch universities have research groups focussing on medical biotech, but most of the universities are also involved in other fields of application. The best profile of edge-cutting biotech research is a listing of graduate schools, which are mainly or partly involved in biotech research or active in fields closely related to biotech. The Royal Netherlands' Academy of Science has recognised 118 graduate schools, which is a recognition valid for five years. Graduate schools can apply for additional recognition after that period of five years. On top of that the Ministry of Education, Culture and Sciences has recognised six of these graduate schools as top institutes. These top institutes are rewarded with additional funding of between 35 and 46 million guilder for a five year period. In biotech the Centre for Biomedical Genetics is a recognised to be such a top-institute. Its orientation is mainly towards health science and 5 universities participate in this project. The second top-institute active in the field of biotech is the project Chemically Designed Catalysts in which Eindhoven University and NIOK participate. In appendix I we have listed the graduate schools, their involvement in different fields, their number of research staff and research assistants (AIO) and the universities and research institutes that participate in these graduate schools (TNO/Enzing, 2000).

3.6. Research structure in research institutes

The Dutch institute for Developmental Biology, also known under the name ‘Hubrechts Laboratory’ is involved in basic research in the field of developmental biology. Most of the subjects studied are related to the treatment of cancer and here we also find the Dutch Cancer Institute, as an institute, as well as a ‘customer’ of research performed by other institutes and universities. Also the Central Laboratory of the Blood-transfusion-service is known for its research in blood related diseases, such as diseases of the immune system, AIDS and haemophilia. The latter two research laboratories are not for profit organisations, private in kind, but public in nature.

The Dutch Organisation for Applied Research (TNO) has two departments working in the field of healthcare, TNO pharma and TNO preventive medicine and health. TNO applies biotechnological knowledge in a wider framework of heart and vascular diseases. The State Institute for Healthcare and Environmental Protection (RIVM) is involved in research in diagnostical applications, especially on the interaction between genetic factors and nutrients, chronic diseases, infectious diseases and development of vaccines.

In the agro-food sector we find the research institutes which formally belonged to the Ministry of Agriculture, Nature Management and Fisheries. (DLO institutes) Although many of these institutes still have a rather independent status, they are reorganised and integrated in the Wageningen University and Research Centre (WUR). Appendix II lists the institutes regarding their research orientation (basic or applied). The ‘volume’ of the institutes is partly given in full-time equivalents and partly in annual budgets (TNO/Enzing, 2000).

4. The institutional environment

4.1. Introduction

Any organisational setup in a given country is influenced by the institutional setup in the economical, social and cultural environment and may provide important resources or, contrary, hamper access to resources. For instance, rules and regulations, may offer security and provide the advantage of predictability, but they can also be obstacles in innovation processes, especially if a regime in one country is more restrictive than in another.

We are interested in the links between the organisational, institutional and cultural environment. How do these links support or hamper innovations? And, if these links exist, are they stable over time? Do they serve as a bridge for the transfer of knowledge, for instance between universities and industry and how are they affected by cultural traits? Our hypothesis is that a high degree of integration between business and the institutional environment will enhance the innovative capacity of a country. In this chapter we will discuss the institutional dimension.

4.2. Strength and weakness of Dutch biotech

Biotechnology has often been regarded to be an engine of sustained economic development, but the high expectations have not come true yet. The number of biotech startups is gradually lagging behind and the eagerness towards biotechnology seems to have disappeared. The second half of the 1990's have been a period of reconsideration. In a 1999 Ernst and Young report the position of Dutch biotech was compared to six other biotech countries and regions. The strength of the Dutch system was its science base, but that was in fact the case in all the other regions. The Ernst and Young report argued that the Netherlands has developed a serious weakness in entrepreneurial culture and there was a lack of incubators. The Dutch performance was only moderate on indicators like venture capital, economic climate and management opposed to frontrunners like the Boston area, Cambridge and Quebec. Strength in science, but weakness in entrepreneurship. 'The need for home grown entrepreneurs and a change of political attitude towards the industry as a whole is vital if the sector is to survive competitively for the future' (Moret, Ernst and Young, 1998, p.50). In more detail the Netherlands has acquired a backlog in the following areas:

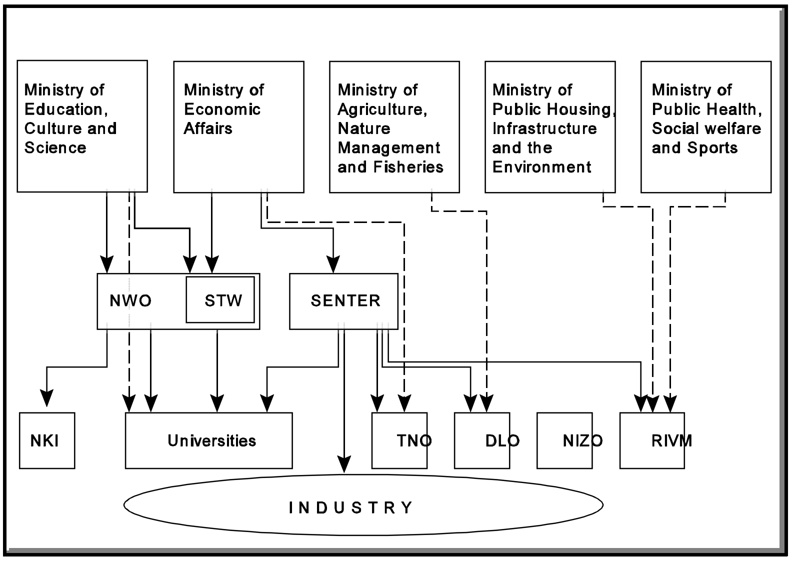
- insufficient 'enterprise spirit' among researchers;
- lack of properly planned startup initiatives;

- lack of incubator facilities;
- insufficient seed capital available;
- limited supply of specialist venture capital;
- inadequate interface between the scientific and commercialised phase.

Given the results of this study the Ministry of EZ has presented the *Life Science Startups Action Plan*, with aan annual budget of 20 million guilders.

4.3. General outline of biotech research

Government is the main supporter of biotechnology research in the Netherlands, but the system of funding differs between ministries. Some ministries have close ties with research institutes or have research institutes as part of the departmental structure, like in the case of agricultural research, environmental care or health care. The biggest part of public research funding is by the Ministry of Education, Culture and Science (OCW) and the Ministry of Economic Affairs, which both channel research funding through specialised agencies. For the Ministry of OCW this is the Netherlands Organisation for Scientific research (NWO), for the Ministry of Economic Affairs, this is Senter.



Afbeelding 8 *National System of biotech funding in the Netherlands*
Source: Enzing, 1999

On first sight it might look like NWO and Senter perform similar tasks, but both organisations differ in that NWO has a large discretion to set up its own programme of research funding, while Senter is rather the executive branch of the Ministry, with less discretion.

4.4. Research funding

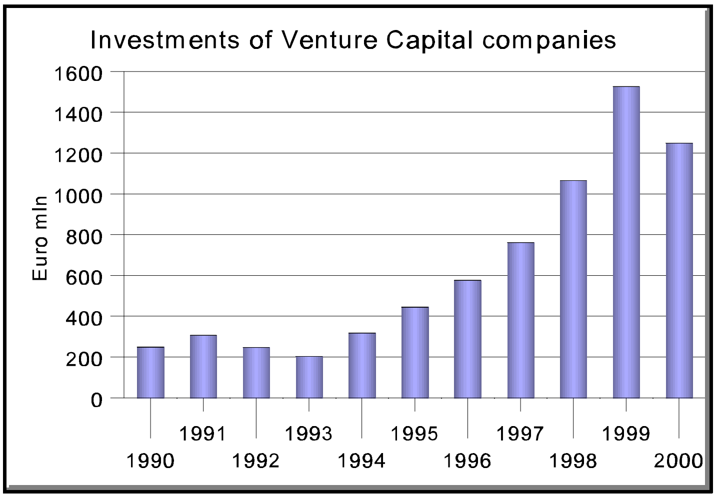
The large vertically integrated firms usually fund research activities from their own budgets and sometime provide a ‘sheltered environment’ which allows young startup companies to develop until the moment that they can stand on their own feet.

Research activities in modern biotechnology are organised in two domains: public and private. However, it is not so easy to make a clear-cut distinction between both domains. Many companies are organised and funded from the private hand although their character better fits the profile of public research, especially when companies spin off from universities and knowledge institutes. These companies are often addressed as hybrid organisations, because they bear characteristics of companies as well as institutions (Fransman, 2001, Etzkowitch, 2000). In general, biotech companies have a high degree of R&D activity, especially when these companies have opted for high risk strategies, such as for instance in drug development. The trajectory from an idea until market-admission as often a trajectory of more than ten years and involves millions of Euros. The critical break-even point in this type of companies is only reached after years of investments and that is why we will start this section with a discussion of biotech startup funding

Schumpeter has put the entrepreneur in the centre of the innovation process as the main driving force. A prerequisite, however, is that the entrepreneur is able to convince banks and other financial institutions to provide him credit to finance the innovation (Schumpeter, 1934:69). Crucial in Schumpeter’s analysis is the relation between lender and borrower. The question if credit will be provided does not so much depend on the properties of the (research-) project as such; it rather depends on the judgement of the lender. No doubt, information about the project is important, but it is not the only touchstone for a decision. Credibility, tradition and interpersonal relations are as important, especially in credit based systems. This was been especially relevant in the decentralised ‘green’ sector, where banks and cooperatives have played such a decisive role in the processes of rationalisation of the sector.

Systems based on credibility especially allow for incremental innovations, but not for risky adventures, which can result in massive profits or massive loss. This is especially relevant for the pharmaceutical industry. Finding a new medicine will possibly generate huge revenues and venture companies are willing to invest in promising companies in the prospect of these revenues.

In general one can say that the Netherlands historically had a hybrid kind of financial system, with important roles for banks as well as the stock market. Nowadays the importance of the stock-market is still further increasing, just like the importance of relative new instruments in the financial funding



Afbeelding 9 *Total investments of Venture Capital Companies in the Netherlands*
Source: NVP/PriceWaterhouseCoopers, 2001

structure, such as seed capital, funds supplied by business angels or venture capital.

Most biotech businesses start with private money, seed capital provided by government initiatives or business angels. Startup capital provides funding for product development and the first marketing activities of startup companies; venture capital provides the funds for sustained growth. These financial instruments usually precede a valuation at the stock market which is often the proof of economic viability for successful startup companies.

The Netherlands have embraced these new financial instrument relatively early. In 1996 it accounted, together with the UK, France, Germany for more than three-quarter of all European venture capital. The importance of venture capital in the Netherlands has especially increased after 1993, with a peak in 1999. Yet, whereas biotechnology -together with ICT related activities- takes a lion's share in the US venture capital structure, this is not the case in Europe. ICT-related companies received only 7% of European venture capital in 1995 and only 5% in 1996. European biotechnology firms received even less. From 1966 both number and size of investments in biotech have increased. (National Science Foundation, 1998).

Year	Total investments (Euro Mln)	Biotech share	Biotech investments
1998	1066	7%	i 74,620,000
1999	1526	4%	i 61,040,000
2000	1248	5.7%	i 71,136,000

1 *Venture capital investments in life sciences*
Source: NVP/PriceWaterhouseCoopers, 2001

The situation in the Netherlands does not fit the European profile. ICT roughly takes one/fifth of all the Dutch venture capital investments. Biotechnology is just a mid-range sector in the Netherlands (between 8th and 5th in a ranking of sectors over several years), with shares between 4 and 7% of all venture investments.

The new systems may have found solid ground, it is not so easy to get access to these systemes. Our interviewees basically paint two pictures. The first is that it has become increasingly difficult to find venture capital. Whereas venture capitalist used to be willing to invest in broad ideas and wild plans, they now have a carefully designed system of selection: *"A starter needs to have a good track-record. In addition to that, the patent position and business plan are important"* according to Marc Wegter of Life Science Partner in NRC/Handelsblad (June 2nd, 2001). Venture capital providers are not only having difficulty to assess the revenues and risks of new products and services, they also are hesitant if a startup company does not have the managerial skills and capabilities. If investors are willing to participate, it is not unusual that they also provide managerial support. In general there is a tendency that venture capital companies tend to turn away from high risk investments (Enzing, 2000, p.16). The second picture is much more optimistic; the venture capitalist desperately looking for high potential startups. These companies [6] have good relations with established biotech companies and it is no exception when their network is used to identify promising ideas and, thus, new businesses.

None of the two tells the whole tale, but both tell a part of the story. The early successes of firms like Pharming or Crucell on the Amsterdam stock market has encouraged more entrepreneurs and venture capitalists to follow the same path and it has helped to create a self sustaining culture of innovation. However, the bankruptcy of the Pharming group might possibly have an adverse reaction.

4.5. Labour market

The increased knowledge intensity of production (processes) has raised awareness on the importance of the factor labour -or human capital- in international competitiveness. Globalization, technological development, quality management and a stronger focus on customer demands has increased the competences of workers. This is especially the case in high tech industries, which have underwent rapid technological change. Established technologies had become outdated and new skills had to be acquired for the application of these new technologies. This development is clearly visible in ICT, but the impact of this process is probably even stronger in modern biotechnology. For example bio-informatics, which has developed at the interface of both technologies, has not only extended the volume of huge databases, but it has also has made these sources of information easy accessible. Computers can process huge amounts of information and high powered computers can perform analysis in a fraction of the time that was needed for the same research several years ago. This has clearly influenced the demand for personnel; 'learnability' and employability is key. This demands a willingness for life-long-learning and a high degree of flexibility. Countries which are able to 'supply' skilled workers have a competitive

[6] Among others: Life Science Partners, the Zernike Group, Atlas Venture, Gilde Investment Management, Euroventures Benelux, ABN AMRO Corporate Investments or Tailwind Investments,

advantage over other countries

Supply of skilled personnel is not a pinching issue in the Netherlands. There is worry for the future though, but at the moment companies are well able to find personnel. Not all positions in biotech companies need to have an academic background; often a company offers employment to a range of low, medium and high skilled laboratory personnel. This is especially the case when the work is basically the application of a single technology in a range of related tests and where variation is relatively low. The Netherlands has a most adequate training system for laboratory staff on all three levels of education. There is training for laboratory personnel, as well as for laboratory technology, providing high level education in the design of laboratory equipment. In agriculture and food, the chemical industry and environmental care the research staff in companies is usually much smaller than in health related fields.

4.6. Education

Even though the Netherlands has a tradition in agriculture and food-production, and even though the Ministry of Agriculture, Nature Management and Fisheries has build up its extensive structure of agricultural research, in general, the science position was relatively weak shortly after World War II.

Two important developments have changed the position of Dutch research for the better. First, the universities have had a massive financial injection, not in the least thanks to state-exploitation of natural gas-resources. This financial impulse has led to an extension of the Dutch research and higher education structure. Second, the university structure was changed in the early 1980's. It was clear that a decreasing number of students opted for a scientific career and broke off their studies before writing a doctoral thesis. Doing justice to an established practice, the university study was split up in two phases. The first four-year phase[7] which was meant to make the students familiar with the ins-and outs of a specific discipline ended with the title *doctorandus (drs)* for general disciplines, *ingenieur (ir)* for technical sciences or *meester (mr)* for juridical sciences. The second four-year phase was meant to train students for a scientific career and ended with a doctoral thesis. The second phase is now organised in thematic graduate schools, in which usually more than one university participates.

Until the 1980's is was usual practice that the division of research funding reacted on research proposals, a rather bottom-up like structure . From 1988 on, when research funding was channelled through the Netherlands Organisation for Scientific Research (NWO), the policies became more active. Graduate schools with performances below par were excluded from government funding, whereas

[7] For medical and several technical sciences five years

excellent research groups were stimulated by prestigious prizes, the privilege of being one of the six *top-graduate schools* and additional funding.

A further important factor for today's excellence is the international orientation of Dutch research. For one part this is a matter of mentality, adaptability to other cultures and multilingualism, but it is also the *need* for international collaboration. The costs of large research projects cannot be beared by single countries and that is why the Netherlands have been in the forefront of several major international research projects.

But there is an additional feature; the Netherlands have an outstanding name in scientific publishing and were amongst the first countries to have scientific journals in German and English. Even now, five percent of all publications in (natural) sciences for instance -which on average have a high citation impact- is printed in journals of Dutch publish houses (Schuyt and Taverne, 2000, p.252-3).

Biology is still the most popular study in the field of natural sciences with a share of 28.5% of all students in natural sciences. Pharmacology holds second place with 16.2%. The trend seems to be that the life sciences biology and pharmacology are increasingly popular and exact sciences like chemistry, mathematics and physics are losing ground.

4.7. Regulation

Many early research projects have taken place in the agriculture and food sector. Risk was mainly perceived in the light of environmental care and thus the Ministry of Public Housing, Spacial Planning and the Environment is the first responsible for the execution of biotech regulations. The guiding principle behind the Dutch regulatory structure is to safeguard safety for humans, animals and the environment; protection of the consumer; and fairness of trade. Some of the regulations are specifically oriented towards modern biotechnology, but others have a much more generic character. The building-blocks for the regulatory framework in modern biotechnology are the following rules and regulations:

- The decree genetical modified organisms and the law on hazardous substances in the environment. This set of rules is basically meant for the protection of humans and the environment and gives a set of rules for the use of GMOs in laboratories and rules for the laboratories themselves. It furthermore outlines the framework for the introduction of GMOs in the environment during field trials and the market admission of GMO's, through a system of licences. In this context there is also a set of rules, especially for the protection of employees.
- Regulations for the use of GMOs in humans and animals. One aspect of this set of rules aims at

describing proper ethical behaviour in healthcare treatment, Another aspect sets out the rules and conditions for scientific research and special treatment (gene-therapy and xeno-transplants for instance). This reach of this decree is to have an instrument to forbid specific types of treatment. Also in the context of this set of regulations, a set of rules regarding welfare and ethics in the treatment of (laboratory) animals.

- Regulation for the evaluation of product quality product safety. In this context one find the rules for the market-admission of foods, drugs, seeds, plants, etc.
- Regulations for the evaluation of the permissibility of pesticides, herbicides and fungicides.
- Regulations on intellectual property, which for instance entails the right of market exclusiveness within the EU for producers of orphan drugs. It also entails a set of supportive measures to increase innovativeness in this field.

In recent years the reach of biotechnology has broadened. The Human Genome project has caused a major shift in thinking about human and animal healthcare and it is to be expected that treatment of disease will change dramatically in the (near) future. However, until now, all treatment systems are base on a diagnose of symptoms when. In the future is to be expected that medical treatment will be based on the constitution of a person, especially in the light of hereditary diseases. Public debate today is whether to set up a screening programme for early detection of diabetes mellitus. This is an enormous change. The emphasis in healthcare is shifting from cure to prevention and thinking about health will undergo considerable changes.

In the light of this perspective it is evident that rules and regulations concerning healthcare need to change. For instance: is all that is possible from a technological point of view also desirable from a ethical point of view? What rules should be applied for insurance-companies if a patient is susceptible to develop a specific disease? Can a company exclude patient from an insurance? And what about the principle of solidarity? Will people with a healthy genetic structure be willing to bear the costs of people with an unhealthy genetic structure? But also more basically, what rules have to be designed to guide the use of biotech products?

These and more question are pressing issues within the Ministry of Public Healthcare, Social Welfare and Sports. Here a project-group has been formed with officers from different departments to study the consequences of the shift in paradigm. The Ministry of VWS has developed a new approach, mainly building on a bottom-up perspective. It is lending its ear to several societal groups, organising discussions, meetings and conferences to generate discussion and list the relevant views. Rules as such are not under construction yet, but there is an attempt to deepen and combine the elements of the discussion and thus to list the similarities and differences in view. It is a method of moving back and forth, exploring views and stimulation discussions. This process is made easily assessable and both pros and cons are carefully investigated. This is a new approach, which has been initiated by the close cooperation between the Ministry and the association of the biotech pharmaceutical industry. Many organisations are involved and the view is that broad support from societal institutions for a regulatory structure is as important as the matter to be regulated itself.

4.8. Government policies

Government has been a strong supporter of biotechnology. Shortly after the application of rDNA technologies it was widely believed that modern biotechnology was one of the key technologies to support further economic development. Stimulating science was regarded the best option to be active in the frontline of biotech development. In fact, aiming at this target has characterised initial government policies in biotech funding. Four phases, each with a slightly different target, and with a large degree of overlap have been set up in the past twenty years. The first phase was a strengthening of the science base, especially in the Innovation Oriented Programme Biotechnology (IOP-b), which started in 1981 and ended around 1987. As this programme has proven to be a good instrument, similar IOP programmes were set up for other economic sectors, but as off 1990 the 'grey' biotech sector (fine chemicals and environmental care) have benefited from the IOP programmes, however, with a different accent in its funding. The PBTS programme [8], which started in 1987, was not so much oriented to the *generation* of knowledge, but rather to the *diffusion* of knowledge. Knowledge transfer was the central theme in the second phase, starting in the mid 1980, but losing ground in the early 1990 to public private cooperation, which was the hallmark of the third phase which has lasted until the turn of the century. Several programmes were implemented, but earlier programmes were often modified in such a way that their targeted character made room for a more generic character. Still, as one of the exceptions, biotechnology was targeted as a sector, while other economic sectors were not supported.

In 1998, the Ministry of Economic Affairs commissioned Ernst & Young to do a benchmark-study and a comparison was made with several other countries or biotech regions [9]. As could be expected in these successful biotech regions, the science base was well developed in each of these regions. However, a lack of commercial spirit was regarded to be the Netherland's weakness. Insufficient 'enterprise spirit' among researchers; lack of properly planned start-up initiatives; insufficient seed and venture capital; and an inadequate interface between the scientific and commercial phases was the main critique. Unlike the

[8] Literally translated: Programmed Business-oriented Technology Support programme

[9] Boston, Cambridge, Berlin Belgium, Sweden, Quebec

most successful regions and countries, the Netherlands did not had a single network linking scientific, industrial and financial players. Furthermore, the policies conducted by government, universities and the availability of good advisors was rather poor. The Netherlands was lagging behind in the number of life science startups was the general conclusion of this report (E&Y, 1998). As a reaction the Ministry of Economic Affairs launched a an action plan, based on three principles:

1. Emphasis should be placed on the stimulation of new commercial activity, next to the more generic programmes (such as for instance the (P)BTS schemes);
2. Government should take the lead in this process and should be the initiator and intermediary;
3. The action plan should involve an integrated approach, in which all phases of commercialisation will be supported.

These principles are elaborated in a five point action plan, which is funded by an annual 20 million guilder budget. The action plan published as the *Life Science Action Plan* entails:

1. The establishment of a life science platform, which will be funded with an annual 3 million guilder budget. This platform aims to be the 'public face' of the programme. It coordinates and monitors activities, it has the role of a broker between the main players (science, industry and finance), but first of all it will try to encourage an 'enterprise spirit' among researchers and management.
2. The provision of seed capital to encourage researchers to conduct applied research, which is specifically targeted at launching their own business and to draw up appropriate business plan. This activity will be funded from an annual 5 million guilder budget.
3. The establishment of incubators to provide the physical environment for life science startups. Incubators provide the specific facilities and supervision, needed for a life science business. It is realised that the annual budget of 5 million guilders in on the low side, but the contribution of the Ministry is mainly oriented to get initiatives off the ground, with local initiators. The aim is to start 5 incubators.
4. The establishment of an equipment fund, facilitating the purchase and deployment of research equipment used by life science startups in the Netherlands. Sharing equipment is key in this programme. The equipment fund has an annual budget of 2 million guilders.
5. The provision of venture capital to finance the initial phase of startups in the life science sector. The investments requirement varies from 0.5 to 1 million guilders per enterprise. The venture capital fund has an annual budget of 5 million guilders.

The Life Science action plan can be regarded to be an umbrella for biotech-related programmes.

Only recently the Ministries of VROM, EZ, LNV, VWS and OCW have presented the 'Integral Working-document Biotechnology', in which the Ministries have given an outline for all biotech related policies[10]. In this working-paper it is expected that developments in biotech will equal developments in ICT and these will have a strong impact in healthcare, agriculture and the food industry, process industry and the environment. Biotechnology may disclose scientific possibilities, but not all that is possible is desirable. It also entails certain risks and ethical dilemmas. Government choses for a responsible system of rules and regulations, which safeguard safety and proper ethical behaviour, but stimulates the Dutch participation in global developments. It has developed a six point action plan:

- Knowledge development and innovation will be stimulated by an innovation-impulse to be executed by NWO. The Life Science Startup Action Plan is regarded to be in an instrument in this policy;
- The use of antibiotics resistant genes will be forbidden in the future. The only exceptions made is the application of the genes nptII and hpt in field trials.
- The discretion of the Commission Genetical Modification will be extended. It will have the role of an independent scientific council, advising government in all biotech related matters.
- Governments aims to extend information on consumer products, so that the customer is able to make an informed decision on what to buy or what to eat. However, the framework for decision is basically European rules and regulations.
- The debate on the ethical and societal dimensions of biotech in food is an ongoing process. Government will start a public debate and the outcome of the debate is an instrument to evaluate biotech policies.
- The foundation of a Commission Biotechnology and Food. This is the steering committee of the public debate and it is responsible for the final report.

On the verge of education and the stimulation of entrepreneurship, an initiative was taken by Niaba, the Netherlands' Biotechnology Industry Association. In 2000 the association has organised its third annual Masterclass Biobusiness in close cooperation with the Management Education Centre of VNO-NCW, the major Dutch employer's association. The Masterclass offers bio technological knowledge as well as managerial and entrepreneurial skills. It has already proven to be attractive and useful to many scientists. It will enhance the chance of success of biotech start-ups and make employees of larger companies more business-minded (Buitelaar and Janssen, 2000).

In interviews, the Action Plan Life Sciences seems to have gotten an ambivalent reception. On the one hand it is valued for its clear contribution to the development of the sector, but on the other hand, its

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[10] The Working Paper has not been discussed yet in Parliament

ambition is regarded too high. 100 million in four years is a lot of money, but if the aim is to support the establishment of 75 new startups, the sum is regarded too low. Furthermore, interviewees advise to concentrate and invest on few potential winners, rather than to support many ideas with few money. Many interviewees wonder if providing venture capital is really a task for government.

4.9. European programmes

An important aim of the European programmes is to enhance the body of knowledge in several field, but, perhaps even more important is the building of international research networks and the dissemination of knowledge. This is especially to create the necessary critical mass to be able to compete on a global level. As the table opposite shows, the Netherlands participate well in EU programmes. Regarding the biotech related programmes BIOMED 2, BIOTECH 2 and FAIR it -roughly- participated in one-third of all projects. It was the coordinating country in approximately 11.5% of these projects.

	Total number of projects		Project coordinated by
	EU total	NL	NL
BIOMED2	703	169 (24%)	7[illegible] (10.3%)
BIOTECH 2	505	206 (40.8%)	61 (12.1%)
FAIR	867	289 (33.3%)	113 (13%)
INCO	1456	229 (15.7%)	112 (7.7%)

2 *Participation in EU programmes and coordination of programs*
Source: Cordis

	Plants	Animals	Environment	Industrial	Cell Factory	Medical	Basic research	Non technological
Austria	—	—	—	M	F	M	F	F
Belgium	M	F	—	M	F	M	F	F
Denmark	F	—	F	F	F	M	—	M
Finland	F	—	F	M	—	M	F	—
France	F	F	—	—	F	M	F	—
Germany	F	—	—	—	—	M	F	F
Greece	F	F	F	F	F	F	—	—
Iceland	M	—	—	—	M	M	—	—
Ireland	M	M	—	F	F	M	F	—
Italy	M	F	—	F	F	M	F	—
Norway	F	M	—	M	—	M	—	F
Portugal	M	F	F	M	F	M	F	—
Spain	M	F	F	M	F	M	M	F
Sweden	—	—	F	F	F	M	M	F
Switzerland	M	—	F	—	M	F	M	F
the Netherlands	—	—	M	M	M	M	M	—
United Kingdom	F	F	—	F	—	M	F	—
M = High Priority; **F** = Average Priority; — = No Priority								

3 *The relative importance of several fields in biotechnology between 1994 and 1998 in 17 European countries*
Source: Reiss, 1999

5. Conclusions

From a recent comparison of the relative importance of several sectors in biotechnology in 17 European countries it shows that most countries have given high priority to biotechnology in healthcare. This is also the case for the Netherlands, but it is an exception in that it has five priority fields, whereas most other countries concentrate on two or three fields. Next to medical applications it concentrates on basic research, environmental care and industrial applications/cell factory. Here we see the strength, but also the Achilles' heel of the Dutch biotech structure.

Biotechnology was regarded to be a most promising field of research, because the fields in which it could be applied could yield from the advantageous prospects. This was especially the case in the food a and agricultural sector and the chemical sector. These three sectors are the most important economic sectors in the Dutch industry and even if only a small share of its products was 'biotech-related', it represented still a massive sum.

Biotechnology had an excellent 'fit' in the dominant concepts for economic development. First of all at fitted nicely in the notions of 'makability' that have been so prominent in the 1970's and 80's; science was thought to overcome many societal problems. But biotechnology also fitted nicely in the system of agricultural research and education. It provided a ready-made structure, which was very much open to the diffusion of new technologies, that could increase productivity and contribute to sustained development.

Also industry was rather open to new applications. Gist/Brocades, which was very familiar with classical bio-technological processes in the food and pharmaceuticals industry, soon took up this new technology and developed a specific strain of yeast to improve the quality of bread, a modern biotech product that was admitted as one of the first in the market.

Organon developed methods for the production of human insulin, now more than twenty years ago. AVEBE, which has developed on the interface of agriculture and industry has recognised the potential and invested millions in research. Biotech also offered new concepts in environmental care, which were most welcome in a country so densely populated and yet, so polluted.

Thus, as soon as modern bio-technologies came available, they fell in fertile ground and developed prosperously, giving the Netherlands a tailwind in biotech research. Several new companies were founded and the Netherlands have been counted among the frontrunners in Europe.

Yet, at the turn of the century, we find the Netherlands surpassed by other countries. Is the decline of the Netherlands in a European ranking caused by lack of entrepreneurial spirit? Are scientists not able to properly plan a biotech startup? Is no seed or venture capital available and is the interface between scientific and commercial phases inadequate?

We tend to believe not. The Dutch pattern of economic specialisation which strongly leans on agriculture and food-processing, makes it vulnerable for public debate. In general one can say that the public's attitude towards biotechnology has always been relatively open. The Dutch business climate has been measured among the most supportive towards biotech applications; only the UK and Ireland are even more supportive (Ballantine and Thomas, 1997, Eurobarometer, 1997, SWOKA, 1998)). Yet, recent discussions on the acceptability of biotech applications have especially hit the food industry and agriculture. The polarisation of the biotech discussion has made industries reluctant. The big supermarket-chains have rejected genetically modified products and thus forced industries to take a low profile on biotech research. Several biotech findings, ready to be used, for instance in beer, cheese or soft drinks, are shelved, because an untimely introduction might easily shy away customers. The same type of discussion has hit biotech applications in agriculture. The Netherlands has been one of the forerunners in the design of a regulatory framework and it has been one of the first countries to set up a good system of environmental rules for biotech research. However, a system developed in the 1980's is not able to absorb all the changing insights which have come to the surface in the 1990's, nor is it able to foresee all the effects of Europeanisation of the regulatory structure. In the Netherlands this has led to inconsistency of the regulatory structure. Certain strains of research , developed according to rules and regulations of the mid 1990's, were no longer acceptable after 1999. This was non attractive climate to set up a new business.

The strength of these discussions is not so much felt in health-care. The unravelling of the human genome has generated an ethical discussion, but in general there is still much more room to move in this field. For the purpose of cure, people are willing to accept much more than they are willing to accept in foods. Yet, the pharmaceutical sector in the Netherlands is rather small and despite the initiatives, it is expected to have a much more moderate growth-pattern than in other countries with a sizable pharmaceutical industry.

The developments outlined above have created a broad and well developed research structure in biotech and created favourable conditions for an early commercialisation of biotech findings. However, changing markets, changing rules and a changing public opinion have made scientist hesitant to step into bio-business.

Appendix I	Bio-medical	Agro/Food	Environment	Chemicals	FTE		EUR	KUN	WU	TUD	TUE	RUG	UL	UM	UT	UU	UvA	VU	Others
					Staff	AIO													
Mainly Biotech oriented																			
Biocentre Amsterdam		F	F	F	23	25											F	F	
Groningen Biomolecular Sciences and Biotechnology Institute	F	F		F	37	106						F							
Experimental Plant Sciences		F		F	32	113		F	F							F			
Food, Food-technology, Agro-biotechnology and Health		F			49	102		F	F					F		F			TNO
Biotechnological Sciences Delft/Leiden		F	F	F	25	79			F	F			F						
Leiden/Amsterdam Institute for Drug Research	F	F			111	72							F					F	
Medical-genetic Centre South-West Netherlands	F				81	93	F						F						
Groningen University Centre for Drug Exploration	F				na	na						F							
Partly Biotech oriented																			
Structures, Functions and mechanisms of Biomolecules				F	49	85				F			F						
Wageningen Institute of Animal Sciences	F	F			22	27			F										
Integrated Bio-medical Engineering for restoration of human function	F				20	38		F		F		F	F	F	F				
Institute of Cellular Signalling	F				43	33		F											
Amsterdam/Leiden Institute for Immunology	F				168	151							F				F	F	NKI, CLB, TNO, DdHK
Developmental Biology	F				29	67										F			NIOB
Oncology Amsterdam	F				47	82											F	F	NKI
Infection and Immunity	F				46	157										F			
Biotech related																			
Biomolecular Chemistry BIJVOET	F				17	49										F			
Bio-membranes	F				36	74										F			
Neuro-sciences	F				109	na											F	F	NIOB IOI
Materials Study Centre	F		F	F	na	na						F							
Debye graduate school				F	56	99										F			
Behavioural and Cognitive Neuro sciences	F				45	72						F							
Molecule Structure, Design ant Synthesis NSR	F				28	19		F											
Heart and Vascular diseases CARMA	F				57	86								F				F	
Netherlands Institute for Research in Catalysis NIOK				F	99	215				F	F	F	F		F	F	F		
Molecular Health Sciences MMPDG	F				147	166	F												
Animal Health GSAH	F	F			90	73										F			
Food, Digestion and Metabolism MENU	F	F			63	76									F	F	F		
Reproduction, Endocrinology and Metabolism DENOVEM	F				28	71		F								F		F	

Source: Ministry of Education, Culture and Science, KNAW, TNO/Enzing, 2000

Appendix II	Bio-Medical	Agro-Food	Environment	Chemicals	Size (FTE or M*f*)
Institutes for Basic Research					
Centre for Bio-Medical Genetics	F				8 Million guilders
Netherlands Institute for Developmental Biology	F				75 FTE
Central Office for Fungicidal Cultures	F	F	F		58 FTE
Netherlands Cancer Institute	F				491 FTE
Central Laboratory for Blood Transfusion Services	F				na
Institutes for Applied Research					
TNO Food	F	F			850 FTE
TNO Institute for Health Prevention	F				150 FTE
TNO MEP and TNO NITG			F		100 FTE
TNO Prince Maurits Laboratory	F				50 FTE
PRI Wageningen UR		F			13 Million guilders
ATO Wageningen UR		F			1 Million guilders
Rikilt Wageningen UR		F			6 Million guilders
ID Wageningen UR		F			20 Million guilders
Netherlands Institute for Dairy Research NIZO		F			na
State Institute for Health Care and Environmental Protection	F		F		na
Wageningen UR for Food Sciences		F			100 FTE

Source: Ministry of Education, Culture and Science, TNO/Enzing, 2000

Appendix III

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			Field of activity					Organisation type					
			Fine chemicals	Agro food	H & A health care	Plant breeding	Environment	Private firm	Graduate schools	Consultants	Laboratory	Research Inst	Association
1	ABN/AMRO Corporate investment									F			
2	AKZO Nobel Pharma				F			F					
3	AKZO Diosynth				F			F					
4	Amersham				F			F					
5	Amgen				F			F					
6	Amsterdam/Leiden Institute for Immunology	*			F				F				
7	Amsterdam Support Diagnostics				F			F					
8	Amsterdam Molecular Therapeutics				F			F					
9	Animal Health	**		F	F				F				
10	Applicon				F			F					
11	Arnold & Siedsma									F			
12	ATO Wageningen			F							F	F	
13	ATO-Agro Technological Research Institute					F						F	
14	Avantium		F		F			F			F		
15	AVEBE		F					F					
16	Aventis Crop Sciences					F		F					
17	BAC			F							F		
18	Base Clear		F	F		F					F		
19	Behavioural and Cognitive Neuro Sciences	**			F				F				
20	Bijvoet Centre for Biomolecular Research	**			F				F				
21	Bio Centre Amsterdam		F	F		F	F		F				
22	Bio Detection Systems			F			F				F		
23	Bio Top Consultancy									F			
24	Bio-Rad Laboratories		F	F	F		F				F		
25	Biogen International				F			F					
26	Biomedical Primate Research Centre				F						F	F	
27	Biopartner Network									F			
28	BioPharma Equities Holding									F			
29	BioPharmind												F
30	Biosynth				F					F			
31	Biotechnological Sciences / BSDL		F		F		F		F				
32	Bird Engineering									F			
33	Cellscreen		F	F		F	F	F					
34	Chiron				F			F					
35	CLB, Sanquin Blood Supply Foundation				F						F	F	
36	Crucell				F			F					
37	Crystallics				F			F					
38	De Baak Management Centre VNO-NCW									F			
39	Debeye Graduate School	**	F						F				
40	Deloitte & Touche Corporate Finance									F			
41	Developmental Biology	*			F				F				
42	DPS engineering									F			
43	DSM Gist		F	F				F					
44	DSM Biologics				F			F					
45	Dutch Patent Office									F			
46	Dutch Institute for Research in Catalysts CARMA	**	F						F				
47	Dyax Target Quest				F						F		
48	Eijkman Grad School Immuno. Infec. Dis. MAG	**			F				F				
49	Ernst & Young									F			
50	Eurosequence				F						F		

Appendix III Page 2		Field of activity					Organisation type					
		Fine chemicals	Agro food	H & A health care	Plant breeding	Environment	Private firm	Graduate schools	Consultants	Laboratory	Research Inst	Association
51	Experimental Plant Sciences, Grad. School / EPS				F			F				
52	Food Digestion and Metabolism MENU **		F	F				F				
53	Food, Food Technology, Agro bio and Health		F					F				
54	Fortis Bank								F			
55	Genencor	F					F					
56	Genetwister Technologies				F		F					
57	Genmab			F			F					
58	Genzyme			F			F					
59	Gilde Investment Management								F			
60	Glaucus			F			F					
61	Groningen Biomolecular Sciences / GBB	F	F	F	F			F				
62	Groningen Univ Institute Drug Exploration GUIDE			F				F				
63	Halotec Delft	F								F		
64	Hanstede Consultancy								F			
65	Heart and Vascular Diseases CARMA **			F				F				
66	Hercules European Research Centre	F					F					
67	Holland Genetics		F	F			F					
68	Hubrecht Lab./Utrecht Grad. School Devel. Biology							F				
69	ID Wageningen UR		F							F	F	
70	ID Lelystad / Institute Animal Science and Health			F						F	F	
71	Infection and Immunity *			F				F				
72	Ingeny International			F	F		F					
73	Inno Tact Consultancy								F			
74	Institute and graduate school Bio Membranes EW **			F				F				
75	Institute for Cellular Signalling *			F				F				
76	Integ. Bio-med. Engin./Rest. of Hum.ane Function *			F				F				
77	IQ Corporation	F		F			F					
78	Isogen Bioscience	F					F					
79	Isotis			F			F					
80	Keygene									F		
81	Kreatech			F						F		
82	Leadd			F					F			
83	Legal Capital								F			
84	Leiden/Amsterdam Cen. Drug Research / LACDR			F	F			F				
85	Licentech								F			
86	Materials study Centre **	F		F		F		F				
87	Med. Gen. Centre South West Neth. / MGC			F				F				
88	MedScience Capital								F			
89	Microscreen, microbial Diagnostics									F		
90	Molecular Health Sciences MMPDG **			F				F				
91	Nepharma											F
92	Neth Org for Scientific Research / NWO			F					F			
93	Netherlands Cancer Institute			F						F	F	
94	Niaba											F
95	NIZO									F	F	
96	Noordelijke Hogeschool / v. Hall Institute	F	F	F		F		F				
97	Novartis Seeds				F		F					
98	Numico		F				F					
99	Octoplus			F						F		
100	Oncology Amsterdam *			F				F				
		Field of activity					Organisation type					

Appendix III

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		Fine chemicals	Agro food	H & A health care	Plant breeding	Environment	Private firm	Graduate schools	Consultants	Laboratory	Research Inst	Association
101	Pam Gene International			F						F		
102	Paques Biosystems					F	F					
103	Pepscan Systems			F			F					
104	Pharming			F			F					
105	Plant Research International		F		F					F	F	
106	Plant Research International / Greenomics		F	F	F					F	F	
107	Praaning Meines								F			
108	Quest International	F	F				F					
109	Regional Development Agencies								F			
110	Reproduction, Endocrinology and Metabolism **			F				F				
111	Rhein Biotech			F			F					
112	Rikilt Wageningen UR		F							F	F	
113	Royal Tropical Institute KIT			F						F	F	
114	Sanbio / HBT			F			F					
115	Schuttelaar & Partners								F			
116	Seminis				F		F					
117	Solvay			F			F					
118	Strategic Biotech International / SBI								F			
119	Structures, Functions and Mechanism of Molecules *	F						F				
120	Swammerdam Institute / SILS	F		F				F				
121	SynCo Bio Partners			F			F					
122	Syngenta Mogen				F		F					
123	Syngenta Seeds				F		F					
124	Tanox Pharma			F			F					
125	TNO MEP and TNO NITG					F				F	F	
126	TNO Food		F	F						F	F	
127	TNO Prince Maurits Lab			F						F	F	
128	TNO preventive healthcare			F						F	F	
129	Unilever		F				F					
130	Univalid			F						F		
131	Utrecht Institute for Pharmaceutical Science UIPS			F				F				
132	Vereenigde (Patent attorneys)								F			
133	VLAG graduate school		F					F				
134	VNCI											F
135	Wageningen Centre for Food Sciences		F							F	F	
136	Wageningen Institute of Animal Sciences *		F	F				F				

* Research Schools partly involved in biotech

** Research Schools Biotech related

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ANNEX I. B4 BIOTECH FINLAND

On the Threshold of a New Technology

Finnish life science industries at the beginning of the 21st century

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Report for the "National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries" project funded by the European Commission/DGXII under the TSER Programme.

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1. CONSTRUCTING A BIOTECHNOLOGY CLUSTER?

1.1 Introduction

Clustering of biotechnology in Finland has up to now taken place mainly within existing industries, such as the agro-food industry, pharmaceutical industry, and wood processing and chemical pulp industry. But some attempts have been made to build up an independent national biotechnology cluster in Finland. One sign of this aim is the founding of the Finnish Bio-industries (FIB) organisation, which currently has 60 member companies from the chemical, food, pharmaceutical, and plant protection industries. Most of them are micro-enterprises located in the biotechnology research centres. Ernst & Young call these kinds of companies '*Entrepreneurial Life Science Companies*'.

The ELISCOs use modern biological techniques to develop products or services to improve the health care of humans and animals alike, to increase agricultural productivity, to support food processing, and to contribute to environmental sustainability by focusing on renewable resources. The Finnish discussion has used the concept of '*discovery company*' to characterise these small innovative companies. The FIB is an organisation that clears social space and positions for newcomers - ELISCOs or discovery companies - in different industrial fields.[1] The FIB, however, is not a catch-all organisation; it is estimated that nowadays 120 to 140 companies operate in the field of modern biotechnology in Finland (Ahola & Kuisma 1998, 7-10).[2]

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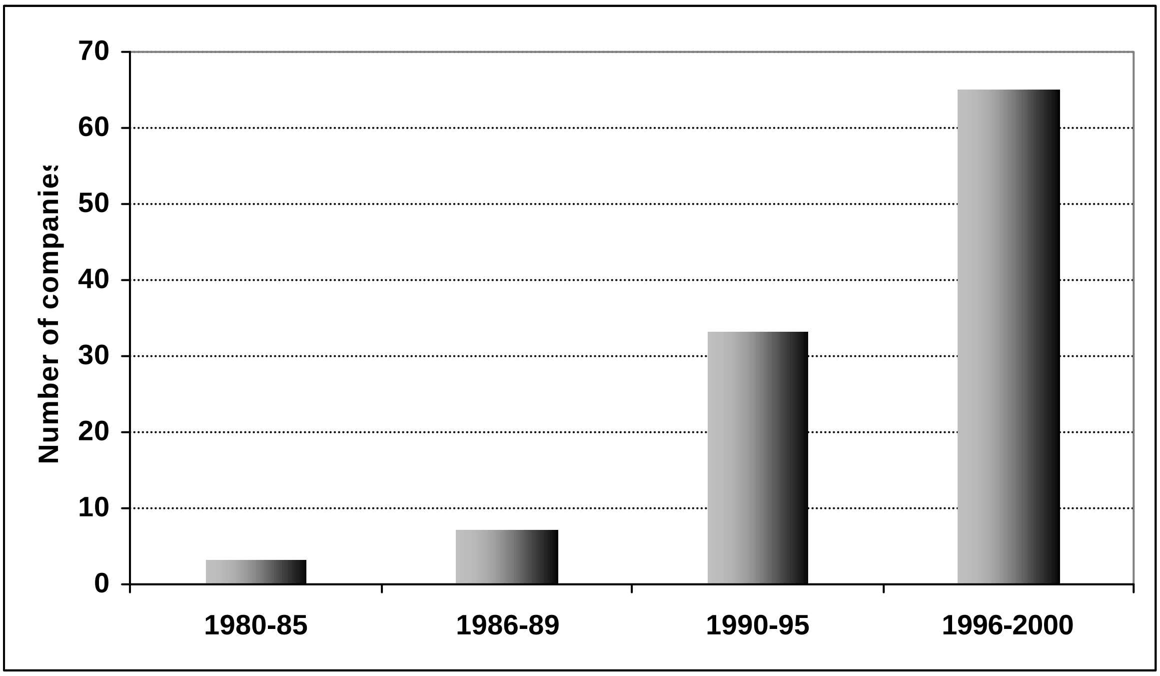
[1] Only half of the biotechnology companies belong to FIB. Half of the FIB member companies operate in the pharmaceutical or diagnostics industries. According to the FIB, the total number of the companies operating in the field of modern biotechnology in agro-food industries is 18.
[2] The number of knowledge-intensive business service companies (see e.g. Miles et al. 1995) in Finnish Life Sciences industries is 28.

Figure 1. Biotechnology industry in Finland — number of companies founded per year



Source: Finnish Bioindustries (FIB) 2001.

Modern biotechnology is mainly applied in the pharmaceutical industry, in biomedicine, and in bioremeditation, as in most European countries (TEKES 1998, 95). Exploitation of modern biotechnology in the agro-food industry as well as in the forest and chemical pulp industries is just taking its first steps. Research and development work on biocatalysts and enzymes seem to produce some promising results (ibid. 95-96). Many of these biocatalysts can be used in the processes of the agro-food and chemical pulp industries. Use of biotechnology in the waste management industry in Finland is rather underdeveloped, although some applications based on modern biotechnology are currently being researched on.

Table 1. Total volume of biotechnology industries in Finland in 2000

Branch	***Number of Companies***	***Turnover (million EUR)***	***Personnel***
Drugs	19	1216	6950
Diagnostics	30	254	2020
Biomaterials	9	14	136
Food and forage	12	250	1000
Industrial enzymes	3	73	287
Agro	6	11	50
Service companies	28	27	270
Others	15	15	100
Total	***123***	***1860***	***10813***
- The ELISCOs	***120***	***663***	***4178***

Source: Finnish Bioindustries FIB, 2001.

Also, the statistics on patents show the central role of the pharmaceutics and medically oriented biotechnology in Finnish Life Sciences industries. More than four fifths of the biotechnology patents belong to the category of drugs.

Table 2. Patents allocated in biotechnology to Finns in Finland, in Europe (EPO) and in the USA in 1989-1998.

	1989	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*Total*
TOTAL	55	75	79	90	76	98	103	142	98	128	944
DRUGS[3]	48	67	70	74	66	83	82	118	79	101	788
Patents allocated in Finland	31	46	39	45	32	40	42	64	24	46	409
Patents allocated in Europe	4	11	11	9	19	28	20	28	22	25	177
Patents allocated in USA	13	10	20	20	15	15	20	26	33	30	202
OTHER BIOTECHNOLOGY[4]	7	8	9	16	10	15	21	24	19	27	156
Patents allocated in Finland	4	2	1	6	2	4	3	4	1	3	30
Patents allocated in Europe	1	1	5	7	7	10	7	12	10	10	70
Patents allocated in USA	2	5	3	3	1	1	11	8	8	14	56

Source: National Board of Patents and Registration in Finland, 1999

1.2 Economic and social importance of biotechnology

The significance of modern biotechnology for the Finnish economy is still limited. In 2000, the turnover of the related industries was estimated to be EURm 1860, which is 1.4 percent of the total GNP. The employment rate in the Finnish modern biotechnological industry is still marginal, even if the number of employees in the industry has doubled in three years. In 2000, the biotechnology industries employed 11,000 people, which is 2.1 percent of the employment in the entire Finnish industry, and 0.4 percent of the total employment. Almost 7,000 people employed in the sector work in the pharmaceutical industry, which is about two thirds of the workforce in this sector. It is estimated that biotechnology-oriented pharmaceutical industry will employ about 14,000 people in 2010. Biotechnology-related employment in process industries, including agro-food industries and enzyme production industries, amounts to 1,500 people. Moreover, approximately three hundred people work in knowledge-intensive business services in the field of biotechnology.

Until today, modern biotechnology has had no significance in the Finnish export statistics. In 1997, the value of exports of high-tech pharmaceuticals was only EURm 23.5, and the value of exports of high-tech chemicals was EURm 52.2. The combined value of exports of both high-tech industries was only 1.3 percent of the total high-tech exports in Finland. Exports of electronics and telecommunications, the strongest high-tech sector in Finland, on the other hand, had a value of EURm 3,800.

[3] IPC patent categories: A61A -A61N, C07B-C07J.
[4] IPC patent categories: C12, A61K 37-39, C07K, G01N 33.

The distribution of venture capital investments represents another good indicator in addressing the importance of a particular industry. In Finland, the total value of venture capital investments in 1997 was EURm 984, of which two thirds were investments from the private sector. Venture capital investments in biotechnology were EURm 4.2, which is only 0.4 percent of total venture capital investments in Finland. However, investing in biotechnology is rapidly increasing. In the year 2000, *Sitra*, the Finnish National Fund for Research and Development, alone invested in the sector EURm 6.3, and the amount is on the increase. Also, private venture capital has become more active, and it is estimated that total venture capital investment doubled in the years 1998-2000. However, as private investment in biotechnology has decreased in the year 2001, the role of public financing has become even more essential.

1.3 Biotechnology – an industrial field for knowledge creation

The ongoing discussion on whether or not biotechnology will become an industrial cluster of its own in Finland is still controversial. So far, modern biotechnology is *de facto* a new method used by various industries in research, development and production. Consequently, modern biotechnology can be seen more as a new technological method or paradigm than an independent industrial sector. As a new technological paradigm or method, it forms the basis on which new technological applications develop. This knowledge basis can be called the arena for the knowledge of the Life Sciences[5]. The situation of Life Sciences within different Finnish industrial sectors can be described as follows: in the case of pharmaceutical industries, there is a network consisting of several ELISCOs but no centre. Correspondingly, in other industrial sectors there are centres, but practically no ELISCOs and Life Sciences networks. Finnish Life Sciences industries concentrate on knowledge creation; there is a lot of – mostly public – investments in research and education. Also, most of the new innovative ELISCOs are dependent on public financing.

2. THE ESSENTIAL ROLE OF THE STATE

The role of the state in Finnish industrial policy has strengthened after the 1960s (Jääskeläinen 2001, 17-25). Particularly in the case of the emerging Life Sciences industries, state support is crucial to further development. Aiming at supporting the building-up of new industries and industrial sectors, the state relies on the following instruments: financial support, education and

[5] In the following, the terms biotechnology and Life Sciences are used in parallel with each other.

legal regulations. In Finland *Tekes*, the National Technology Agency, is the main financing organisation for applied industrial research and development, whose funds for financing are allocated from the state budget via the Ministry of Trade and Industry. *Sitra,* the Finnish National Fund for Research and Development, supports promising start-up enterprises. The third public financing institution is the Academy of Finland, which supports scientific basic research in universities and research centres.

It is widely believed that especially in modern biotechnology a flexible innovation network plays a significant role in generating new knowledge and innovations and in exploiting them for commercial purposes. In various countries, technology policy programmes to foster growth in biotechnology have given particular attention to regional proximity, based on the assumption that intensive social exchange relations are necessary in generating innovations (e.g. Audretsch & Stephan 1996). Finnish technology policy has also followed the mainstream aiming at the development of regional biotechnology clusters, by copying the 'Silicon Valley model' (see e.g. Saxenian 1994): almost twenty new Centres of Expertise were founded in the country in the 1990s, six of these centres operating in modern biotechnology.

2.1 Centres of Biotechnological Expertise

The Finnish Ministry of Education established the first National Research Programme on Biotechnology in 1987. The aim of the programme was to develop four powerful centres of biotechnological expertise by 1992. These new centres were planned operate in affiliation with those Finnish universities assessed as having the capacity and resources to develop this new field of scientific research. The centres of biotechnological expertise were set up in Helsinki, Turku, Kuopio, and Oulu. By the end of the five-year programme period, the Ministry of Education made an evaluation aiming at identifying needs to further develop biotechnology and molecular biology. The Ministry decided to continue the programme, and later on, the programme period was extended until 2000 (Jäppinen & Pulkkinen 1999, 10-13).

Besides the Ministry of Education, the Ministries of Trade and Industry, Agriculture and Forestry, and Social Affairs and Health also participated in the financing of the biotechnology research programme. The four centres of biotechnological expertise became part of the Finnish network of the Centres of Expertise. As Figure 2 shows, besides in traditional centres, research and development in biotechnology is nowadays also conducted in new centres placed in Tampere and Seinäjoki.

In Finland, the Centre of Expertise Programme has become the core of the newly developed regional policy. Centres of Expertise offer local companies business services and forge links between regional enterprises and local universities or – in some cases – local polytechnics. They are presumed to be sources of knowledge for regional economies. Centres of Expertise are also expected to generate new forms of business, to support the foundation of new enterprises, and to create a stimulating environment for the techno-organisational modernisation of the existing companies (Tulkki 1997). The policy has been criticised, however, for its excessive decentralisation of the limited R&D resources. (Kekkonen & Nybergh 1999, 18-20).

There is some kind of division of work between the Finnish centres of biotechnological expertise. Four biocentres, Oulu, Turku, Tampere, and Kuopio focus on medical research and co-operation with the pharmaceutical industry. Helsinki Science Park and Foodwest in Seinäjoki focus on co-operation with the agro-food industry; biotechnological research and development oriented to agro-food industry also takes places in the biotechnology centres of Kuopio, Oulu, and Turku (see Figure 2).

The dominant status of the pharmaceutical industry in the field of Finnish biotechnology can partly be explained by the fact that this was the focus area of the 'old' Centres of Expertise. As the centres that concentrate on R&D in agro-food have been established only recently, the area is still lagging behind in its economic importance. For instance, Foodwest, a science park established only recently, has not been able to promote new knowledge-based enterprises so far. However, there are several 'old' agro-food companies and units of large companies in the region.

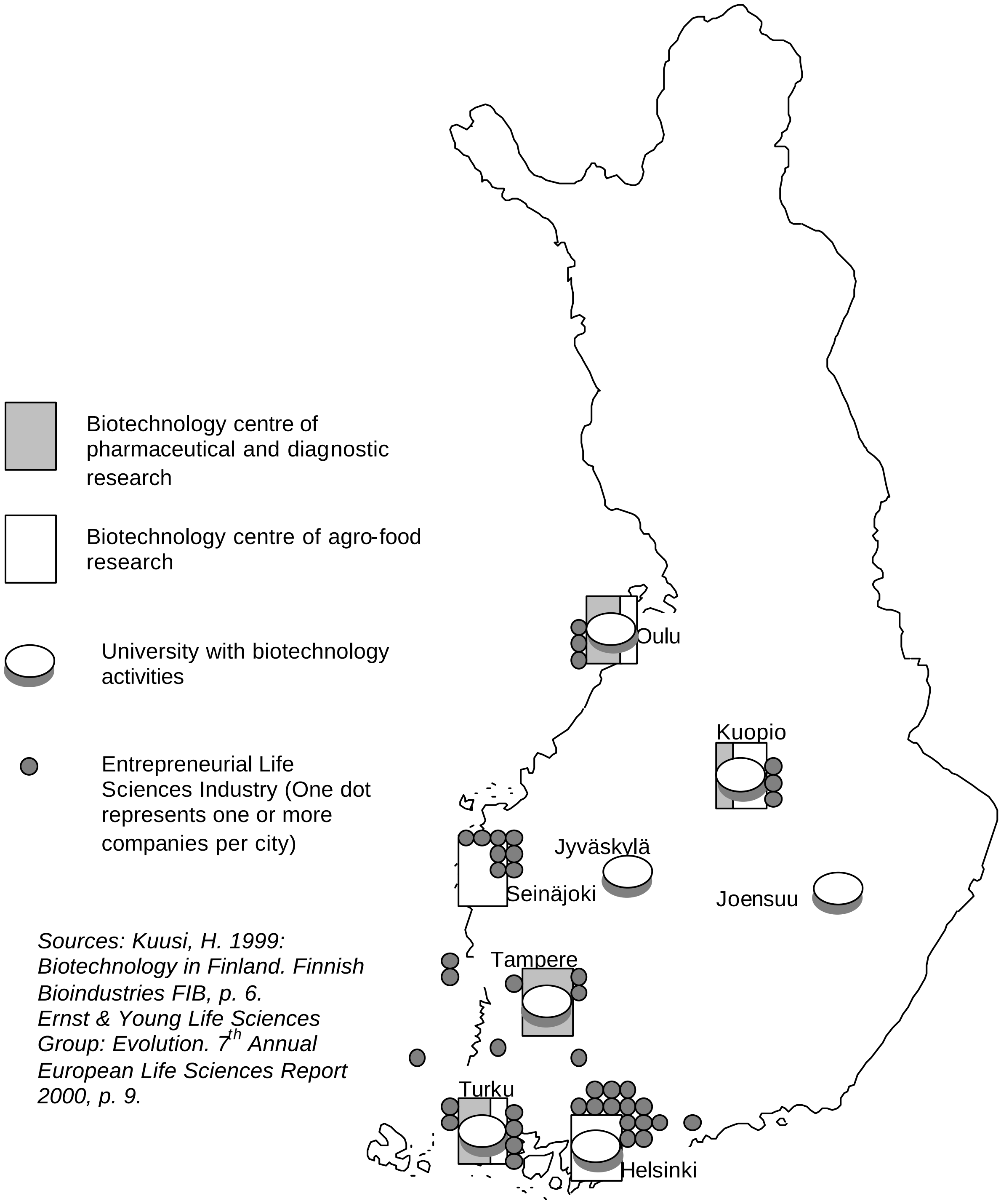


Figure 2. Universities, Centres of Expertise, and the locations of biotechnology business firms in Finland in 1999

2.2 Education in biotechnology

Modern biotechnology relies a great deal on formal education, as – according to Lundvall (1999) – knowledge in this field is highly codified (see also OECD 1996, 14-15; Hatchuel & Weil 1995). This is reflected in the fact that Finland has invested a lot in education in the field of biotechnology in the recent 15 years. However, there is still a lack of highly skilled labour in this industrial sector, which is often seen as the main factor delaying its development. Some companies, even innovative micro-firms, have been forced to recruit experts from abroad, and some large companies explain their cuts in R&D expenditures in Finland by the lack of skilled and highly qualified employees.

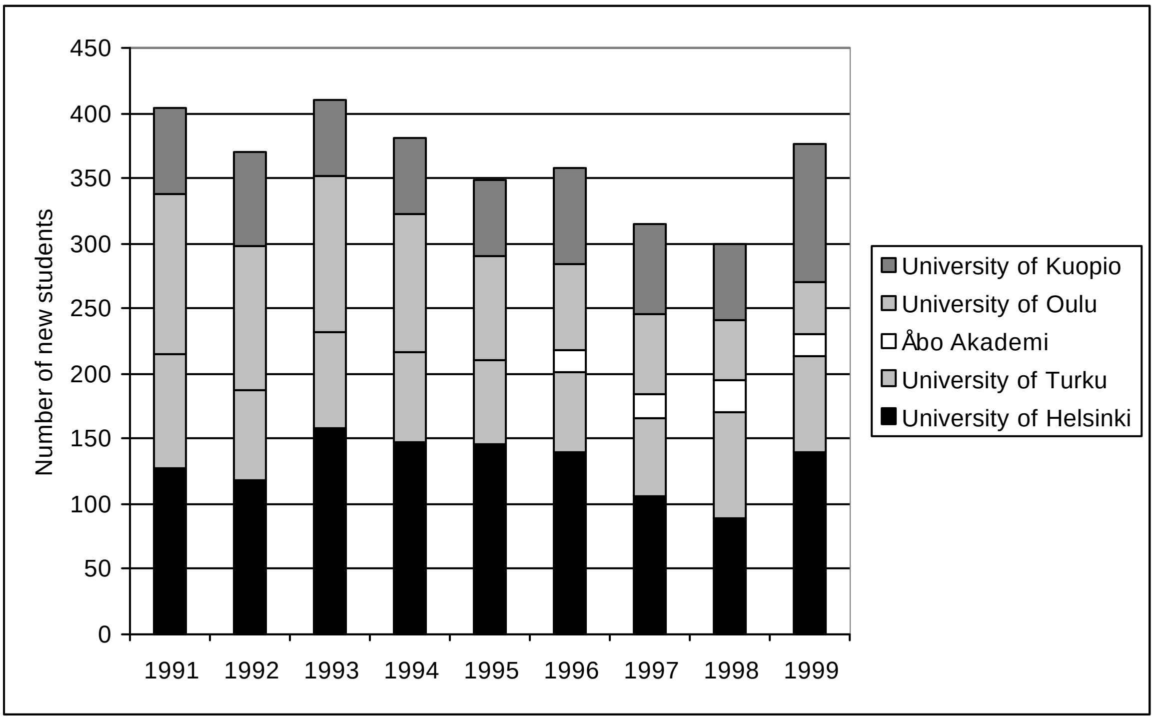
Bio-engineers have been educated at the Helsinki University of Technology since the mid-1980s. In 1998, a special master's programme in biotechnology was established at the University of Turku. Each year 20 students begin their master's studies instructed jointly by the Faculty of Medicine and the Faculty of Mathematics and Science. The programme trains the students to meet the need for expertise in the pharmaceutical and food industries. Their studies include chemistry, biochemistry, cell and development biology, molecular biology, genetics, and human biology but also business administration and economics. One idea and goal of the training programme is to promote new entrepreneurship in the field. Students write at least a part of their master's thesis working in biotech companies or laboratories. (Väänänen 1999, 44-47)

In 2000, sixty new students started their studies in a new training programme in biotechnology at the University of Kuopio. It consists of three main subjects: animal biotechnology, plant- and agro-biotechnology, and nutritive and food biotechnology. In animal biotechnology, research and teaching concentrates on genetically modified mammals and fish. In plant- and agro-biotechnology, the emphasis lies on increasing the productivity of crop, the prevention of plant pests, and environmental biotechnology. In nutritive and food biotechnology, the focus is on the health-advancing attributes of food. (Lindqvist 1999, 41-43)

In Viikki Science Park in Helsinki, about 3,000 students study different subjects in biotechnology (Halme 1996). Also, Finnish polytechnics offer training programmes in biotechnology. However, the number of students in this discipline is not yet comparable with the number of engineering students. At the university level, about 500 students start their studies in biotechnology yearly, whereas about 5,500 students start their engineering education, almost one third of them in information and telecommunications technologies.

The complexity and multidisciplinary nature of modern biotechnology makes it very difficult to identify those students whose education is directed to modern biotechnology in other disciplines than medicine. Figure 3 shows those non-medical training programmes whose linkages with the biotechnology business are obvious. The total number of the students passing the entrance examinations of universities in the biotechnology outside medical faculties did not increase in the 1990s. In polytechnics, the intake of new biotechnology students was 267 in 1999, which is only 0.8 percent of the total student places. These numbers mean that no additional investments in the basic degree education in biotechnology outside medical faculties have taken place. While in modern biotechnology the pharmaceutical industry is dominating, the focus of education is on the Faculties of Medicine.

Figure 3. Intake of students in biotechnology in Finnish universities in 1991-1999



Fourteen graduate schools have been established at Finnish universities supporting research in various areas of biotechnology (Makarov 1999, 21-23). Five of them are situated in Helsinki, four in Turku, two in Kuopio, and one in Oulu, Tampere and Joensuu, respectively. The locations of the graduate schools give some hints about the future strongholds of the Finnish biotechnological industries as they integrated into regional biotechnology Centres of Expertise; the Helsinki and Turku regions will most likely become the centres of biotechnology industries in Finland. As Table 3 shows, most of the graduate schools operate in various areas of medicine.

Table 3. The graduate schools of biotechnology in Finland

University	Graduate Schools
University of Helsinki	• The Biomedical Graduate School • The Graduate School in Neurobiology • The Finnish Graduate School on Applied Bioscience • The Graduate School in Biotechnology • Viikki Graduate School in Biosciences
University of Turku	• The Graduate School of Biomedical • The Finnish Graduate School in Musculo-Skeletal Problems • Biological Interactions Graduate School
Åbo Academi (Turku)	• The Graduate School of Informational and Structural Biology
University of Oulu	• Biocenter Oulu Graduate School
University of Joensuu	• The Graduate School in Forest Sciences
University of Kuopio	• A. I. Virtanen Graduate School

2.3 Financing

Research and development in biotechnology is highly dependent on state funding. As mentioned earlier, only 0.4 percent of private venture capital investments were directed to biotechnology in 1997. Different parts of the idea-innovation chain are financed by different institutions. The Academy of Finland is supporting scientific basic research in universities and research centres. *Tekes*, the National Technology Agency, concentrates on applied research and product development by supporting the co-operative activities between university research and companies. The role of *Sitra*, the Finnish National Fund for Research and Development, is to support promising start-up enterprises. Later on, new knowledge-intensive companies are expected to get their financing from the capital markets.

Tekes has invested EURm 90 in the fields of chemistry and biotechnology, which accounts for 27 percent of its total investments. The Academy of Finland and *Tekes* invest about EURm 3.4 yearly in research on biosciences and biotechnology as part of the Centres of Excellence Programme[6]. In addition, the two institutions have also invested EURm 0.7 in Biocentrum Helsinki, Biocenter Turku, and BioCity Turku. The National Programme for Research on Biotechnology, started in 1988, invests about EURm 13.5 yearly in biotechnology (Vihko & Pauli 1999). Since the state financed Finnish biotechnology quite extensively in the 1990s, some criticism has been raised about the results of this massive investment.

There have been two research programmes in the field of biotechnology, financed jointly by *Tekes* and the Academy of Finland: the Genome Research Programme and the Cell Biology Research Programme. The Genome Research Programme focuses on gene regulation, studying

[6] In 2000, a total of 26 new Centres of Excellence were established, nine of which are operating in the field of modern biotechnology and biosciences.

interactions between several genes and gene products, gene transfers and knockouts as well as gene therapy. The budget of this six-year programme amounted to EURm 15. The Cell Biology Research Programme studies mechanisms of cell division and differentiation, biogenesis of cell organelles, and intracellular trafficking as well as signal transduction. The programme started in 1998 and will continue until the end of 2001. Its budget amounts to EURm 5.4. Together with the Academy of Finland, *Tekes* has recently launched the technology programme 'Medicine 2000'. The programme addresses biomedicine, medicine development and pharmaceutical development, and it will end in the year 2006. The budget of the programme may total up to about EURm 150.

In 1993, the Ministry of Education established a new Centres-of-Excellence policy by ordering the Finnish Higher Education Evaluation Council to choose ten units and institutes as 'top units' (Ketonen & Nyyssölä 1996, 68-73). This policy of establishing Centres of Excellence has become the core of the Academy of Finland’s research policy (Vihko & Pauli 1999, 15). The Academy expects that the new policy can lead to a strong concentration of research and innovation capacity. Currently, 6 percent of the Academy’s funding is directed to the Centres of Excellence Programme.

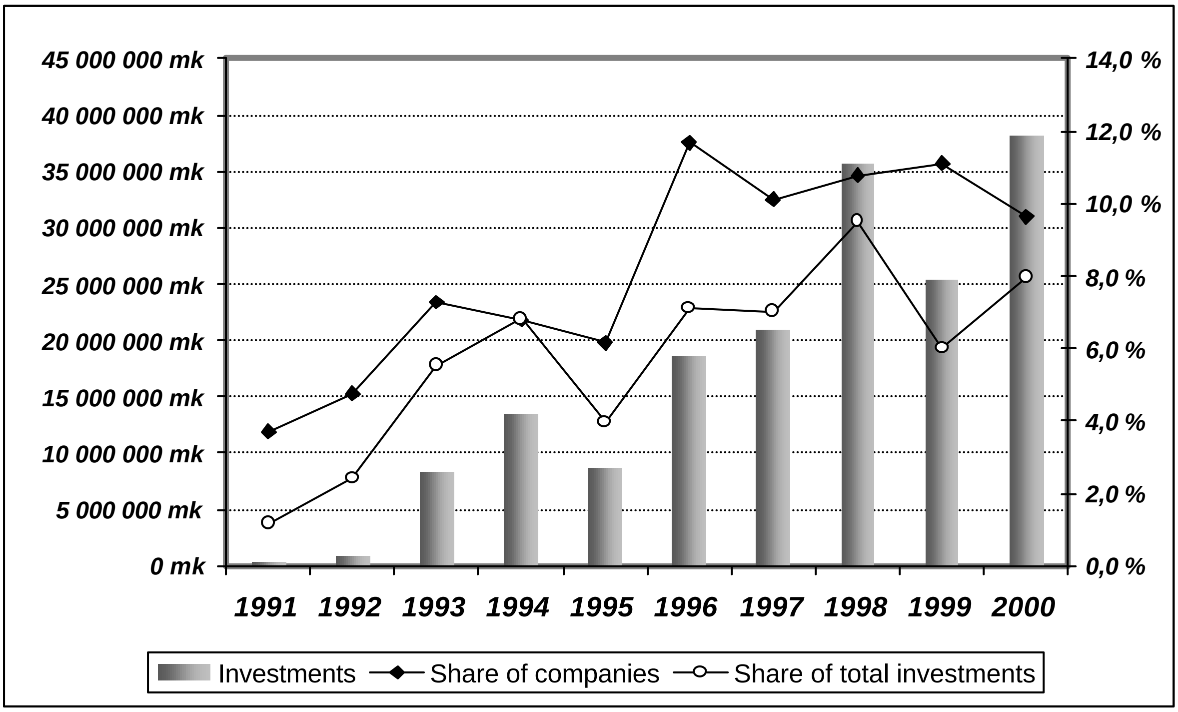
The Academy of Finland also finances research in modern biotechnology within its basic research programmes. In 1999, the Research Programme for the Biology of Structures started and, in 2000, a Research Programme for Biological Functions was being planned. Furthermore, the Academy of Finland finances the Research Programme in Molecular Epidemiology and Evolution. The primary areas of this programme are population genetics, concerned particularly with the evolution of genes, the adaptation of organisms to extreme conditions, genetic epidemiology and the Finnish genetic heritage, and environmental molecular genetics, including genetic factors predisposing to disease.

Tekes started a five-year Biotechnology Development Programme in 1988. It consisted of five areas important to Finnish industry: biotechnology for the pulp and paper industries, bioprocess engineering, plant biotechnology, animal cell technology, and biologically active molecules. *Tekes* also has an agro-food biotech programme named ‘The Innovation in Foods Programme’. The goal of the programme is to ensure the production of increasingly top-quality products by improving the standards of food technology and related research in Finland. The programme started in 1997 and continued until 2000. The budget of the four-year programme was over EURm 33. All significant Finnish agro-food companies participated in the programme.

In 1991, *Sitra*, the Finnish National Fund for Research and Development, invested EUR 67,000 in biotechnology with the aim of financially supporting new start-ups. This was only 1.2 percent of its total investments. Nine years later, *Sitra*’s investments in biotechnology amounted to EURm 6.5. Today biotechnology is one of the most strongly supported industrial branches in

Sitra´s portfolio; it has investments in eleven biotech companies. The share of its biotech investments accounts for as many as eight percent of its total investments. In 1997, two special funds, Sitra Bioventures Ky and Sitra Bio Fund Management Ltd, were started with a capital of EURm 25. In 2000, one of the new start-up ELISCOs promoted by *Sitra*, BioTie Therapies Oy, was listed on the Helsinki Stock Exchange, and "new listings are in the pipeline".

Figure 4. *Sitra's* investments in biotechnology in 1991-1998



2.4 Legislation and regulations

The control over the pharmaceutical products and medical devices is concentrated under the administration of the National Agency for Medicines. The Agency works under the Ministry of Social Affairs and Health to maintain and promote the safe use of medicines, medical devices, and blood products. The National Agency for Medicines has three departments: the Pharmaceutical Department, the Pharmacological Department and the Department of General Affairs. Its other units are the Secretariat for Marketing Authorisations, the Inspectorate, the Drug Information Centre, and the Medical Devices Centre.

The Pharmaceutical Department carries out and administers quality assessment related to applications for marketing authorisation of medicinal products and herbal remedies. The post-marketing quality control of medicines and the research related to quality control activities also belongs to the department's sphere of responsibilities.

The Pharmacological Department assesses the documentation related to applications for marketing authorisation of medicinal products and veterinary medicinal products. The Medical Devices Centre, besides maintaining the product control registers and implant registers, is responsible for the assessment of applications for clinical investigations of medical devices and the supervision of marketing of medical devices. The centre carries out and administers standardisation of medical devices in Finland. The Secretariat for Marketing Authorisation handles the regulatory affairs concerning marketing authorisations and procedures.

In addition, a voluntary control system in marketing of medical products exists in Finland. All member companies of Pharma Industry Finland (PIF) have agreed to comply with the Code for Marketing of Medicinal Products, which is monitored by the Supervisory Commission for the Marketing of Medicinal Products and by two Inspection Boards working under the Commission.

The National Food Administration is a body under the authority of the Finnish Ministry of Trade and Industry. It controls the production, import, serving, and sales of foodstuffs in Finland under the Food Act, the Public Health Act, and various EU directives. These laws and regulations fall within the sphere of the Ministry of Social Affairs and Health. The National Food Administration also carries out management tasks in its field for the Ministry of Agriculture and Forestry. At the practical level, local authorities control food with the assistance of the provincial state offices or regional state authorities.

In 1999, the Finnish Parliament enforced the Gene Technology Act (377/1995) and the Council of State the Gene Technology Statute (821/1995), which led to the constitution of the Board for Gene Technology. In addition to being a national authority in Finland, the Board functions as a competent authority towards the European Community. Genetically modified foodstuffs and the genetically modified components of the foodstuffs belong to the sphere of influence of the EU's Novel Food Directive (258/97/EY). In their case, the acting authority is the Board of Novel Food. The Board is located at the Ministry of Trade and Industry, and its duty is to evaluate the novel food products aimed at being sold on the Finnish markets. The Board also evaluates the applications in other countries.

The Advisory Board of Biotechnology is a consultative administrative body appointed by the Council of State. The work of the Advisory Board is based on the Gene Technology Statute (821/1995) with a three-year mandate. One of the Advisory Board's main tasks is to boost the co-operation of the state authorities and other actors in the field of biotechnology. It also monitors the international co-operation and research considering the development of modern biotechnology. Another important task is to promote research and education in biotechnology. Ethical questions concerning biotechnology also belong to the responsibility of the Advisory Board.

3. THE NETWORKS OF BIOTECHNOLOGY COMPANIES

3.1 The core of biotechnological industries: the pharmaceutical industry

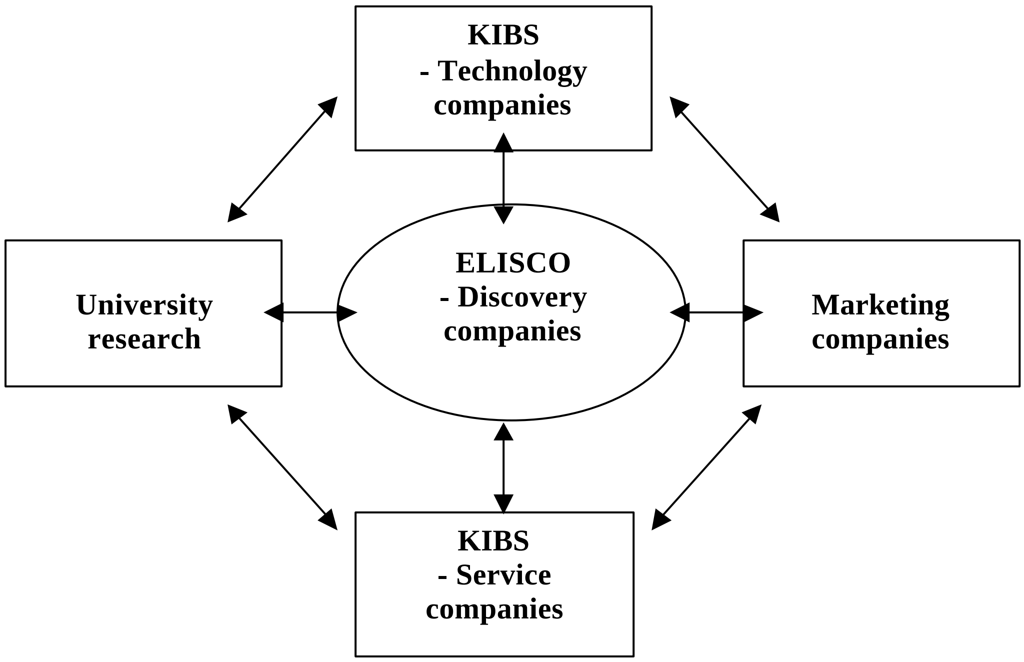
In the Finnish industrial policy discourse, as mentioned earlier, biotechnology is mainly associated with the pharmaceutical industry (Jalkanen 1998). The leading role of the pharmaceutical industry can be explained to some extent by the fact that the workforce in this sector is traditionally highly skilled with many academics, having a degree in medicine or technical sciences, working in R&D departments. The fact that private ownership is dominating in this industry while it is not in other biotechnology fields may be seen as an important factor as well (Rannikko and Tulkki 1999). Public opinion is also supportive; because of the careful clinical testing system and the regulations in medicine industries, people accept biotechnological solutions in drugs more easily than in other product branches. (Jauho and Niva 1999).

The crisis of the pharmaceutical industry in the beginning of the 1990s may also have contributed to the dominance of medicine in Finnish biotechnology. Many companies in the industry changed their strategies and abandoned their biotechnological research and development actions and departments. As a consequence of this, many highly educated employees in companies' R&D laboratories lost their jobs and began to start their own small R&D firms.

The Orion Group is the leading Finnish company specialising in products for the health-care sector. Orion is now the only Finnish firm that operates across the entire pharmaceutical idea-innovation chain. Earlier another company, Leiras Oy, operated to an equal extent. But after 1996, when Schering AG acquired Leiras Oy, the basic research and development activities were reassigned to Germany. In 1999, the Orion Group's net sales were EURm 912, of which international operations accounted for EURm 330. Two thirds of the Orion Group's net sales come from the Finnish market, one quarter from the European markets and ten percent from the North American or other markets. The number of personnel in the continued operations was 5,172. In 1999, the Group's research and development expenditure was EURm 68, which is 7.4 percent of the total net sales of the corporation. The Orion Group is composed of four divisions: Orion Pharma, Oriola, Orion Diagnostica, and Noiro. Orion Pharma and Orion Diacnostica concentrate on products based on biotechnological research and development work.

The founding of the centres of biotechnological expertise has changed the structure of the Finnish pharmaceutical industry significantly. Nowadays, a network of ELISCOs and KIBS firms situated in the university-affiliated biotech Centres of Expertise has become a key actor in this industrial sector. These enterprises can be divided into three different types. Firms belonging to the first type concentrate on research and development activities, companies of the second type specialise in knowledge-intensive business services, and companies of the third type focus on the production of supporting technologies. Some global pharmaceutical companies also have smaller units in Finland and in Finnish biotechnology centres. In addition to enterprises, the Centres of Expertise also host university institutes and private research institutes.

Figure 5. The pharmaceutical idea-innovation network in Finland



Source: Lammintausta 2000

The new university-affiliated biotechnology centres have an important role to play in the research and development activities of the pharmaceutical industry. BioCity in Turku, Biocenter in Oulu, and the A. I. Virtanen Institute in Kuopio all work in the field of medical and diagnostical research. They have strong linkages to the pharmaceutical industry, but they have also been criticised for excessive distribution of their limited recourses. These Centres of Expertise take in a lot of small firms, spin-offs either from universities or larger pharmaceutical companies.

The Turku area in the southwestern part of Finland has attracted a remarkable number of Finnish pharmaceutical companies. To further develop this industrial agglomeration, the City of Turku has made large investments in modern biotechnology. One reason for the heavy investments made by the local government in biotechnology is the strong medical industry in the area; another the fact that the City did not participate in the rapid development of the Finnish information and telecommunications technology.

After the economic crisis at the beginning of the 1990s, the Finnish pharmaceutical industry did not only restructure, but also a number of mergers and take-overs took place, and some companies went bankrupt. Still, Finnish pharmaceutical corporations are small, which makes it difficult for them to hold their own on the global markets. Because of the limited scope of the national pharmaceutical industry, the most R&D-oriented companies in Finland look for co-operation with global corporations.

3.2 Green and red biotechnology in Finland

3.2.1 The agro-food industry

Nowadays conservatism and less favourable attitudes towards technological development are the main reasons for the low innovation capacity of the Finnish agro-food industry in the field of biotechnology (Salo et al. 1998). Also, exaggerated expectations concerning return on investment, the fear of technological risks and the lack of skills and competence in modern biotechnology can be seen as significant factors that have hampered biotechnology-related R&D activities in the Finnish agro-food industry.

The delayed transformation of the Finnish economy and society contributed to the high status of farmers in Finland. In Finnish agro-food industry, the farmers, their unions and their co-operatives represent the most relevant group that has an influence on the techno-economic development. Most of the agro-food industrial mills, creameries, slaughterhouses and food factories have been owned by the farmers' production co-operatives. The share of privately owned companies in the food industry is very limited and they are rather small by size.

The modern-biotechnology-oriented agro-food industry is divided into two sub-fields. In the core of the field are the large established companies, such as Valio, Raisio, Danisco-Cultor, and Fazer. They all have a long history and a strong tradition as key actors in the former national 'agro-food industrial complex'. On the one hand, their monopoly position has delayed the regeneration of these companies. On the other hand, the expansion and impact of the European and global markets has forced companies to strengthen their competitiveness by undertaking fundamental restructuring processes. The development of R&D activities in modern biotechnology is seen as a part of the renewal process in these companies. Strengthening R&D is often achieved through mergers or co-operation agreements with foreign companies. The former Finnish Cultor, for example, merged with Danish Danisco in 1999, and other large Finnish companies have concluded co-operation agreements with global companies or are seeking partners among them.

Global agro-food companies, such as Monsanto and Rhône-Poulenc Agro, have set up sub-units in Finland. These units are seeking and keeping up co-operation with Finnish companies, universities, and research centres. They are also monitoring the development of biotechnological R&D in Finland, and in some cases, they carry out R&D of their own. But due to recent developments such as the spread of the BSE, some of these global companies have lost interest in applying modern biotechnology in the agro-food industry. Monsanto Oy, for example, has turned its focus totally to modern biotechnology research and development of Finnish pharmaceutical industries.

The closed nature of the Finnish agro-food industry has hindered the formation of biotechnology-based new start-ups. There are, however, some innovative, small agro-food companies operating in the field of biotechnology in Finland. These ELISCOs do not engage in production; some of them concentrate on research and development of new products; others on creating the technology needed in modern biotechnology-based R&D. Usually these start-ups are partly owned by *Sitra*, the Finnish National Fund for Research and Development. Two thirds of these companies were founded in 1998 or later.

The most rapid development in modern biotechnology research takes place in the state-owned and state-aided research centres. The Agricultural Research Centre of Finland (MTT) and the Institute of Biotechnology at the Technical Research Centre of Finland (VTT) have both taken significant steps in the research and development of biotechnology. Also, the new biotechnology research centres take part in the progress. These research centres, and not the industry focusing mainly on production, are the front line actors in Finnish biotechnology.

The established centres have been a significant part of the ago-food industry for a long time, and their relations and linkages to leading companies are broad and strong. The position of the new biotechnology centres is less established. But the technological and knowledge base represented by this institutional structure may create preconditions for re-constructing the configuration of the Finnish agro-food industry. There are some signs that the whole agro-food sector in Finland will undergo major changes, turning into a research-intensive, modern biotechnology-based food production.

The aim of the Agricultural Research Centre of Finland (MTT) is to promote the competitiveness of the food industry, the liveliness of the countryside, and the pleasantness of the environment by producing R&D services. Results of the research work are applied in order to lower production costs, improve the quality of foodstuffs, and decrease damages to the environment. The centre is strongly focused on the research and development of foodstuffs. The MTT is currently planning to experiment with production of genetically modified cheese and it has started researching on GM animals. The primary goal of the MTT's Food Research is to promote domestic food production and food processing in accordance with the principles of sustainable development. The unit also analysis possibilities to create services related to food composition, nutritive value, and safety.

Several Finnish universities and state research organisations co-operate with the MTT on various scientific research projects. The MTT's most important co-operation partners are the large Finnish agro-food companies and Finnish farmers. For example, research and development work on cheese is done in the MTT in co-operation with Valio. Other Finnish partners are agricultural advice organisations, businesses of the agricultural and food industries, and educational establishments. Co-operation between the MTT and the new biotechnology centres, on the other hand, takes place only occasionally. There is no division of tasks between the two camps in their research areas. Co-operation of the MTT with universities takes place on a traditional basis: there are several students working on their theses in the MTT's laboratories and the Research Centre is involved in scientific post-graduate education. The MTT's main partners are the Universities of Helsinki, Turku, Oulu, and Kuopio, but the Research Centre also co-operates with universities abroad. Besides the EU and other European countries, it has partner institutes in the United States and China, for example.

VTT Biotechnology was founded in the mid-1960s. The unit uses biotechnology and biological materials in its research and development work to create innovative processes and products to promote sustainable development and to improve the competitiveness of its industrial customers. Research and development work is carried out in interdisciplinary, joint projects with research partners in industry and at universities. The institute employs a total of 300 people and its turnover of the unit amounts to EURm 20. VTT Biotechnology has worked in close co-operation with Primalco Ltd, Rôhm Enzym Ltd. and Danisco among others; in general, it has stronger linkages to universities of technology than to the MTT. At the beginning of 2000, one research group in the institute was promoted to a top research unit by the Academy of Finland.

3.2.2 The wood processing industry

In Finland, the production and export of chemical pulp has been comparatively high, which ultimately is a semi-manufactured product and raw material to the paper industry. The manufacturing of chemical pulp is a representative example of mass production. For a long time, one problem of the Finnish wood-processing industry has been the low degree of horizontal process integration. This is a resultant of the Finnish so-called smallholding policy; two thirds of the Finnish forests are nowadays privately owned by farmers or testamentary heirs of ex-farmers, one quarter belongs to the state, and only 8 percent to corporations.

Due to this situation, some kind of dichotomy in the production chain of wood-processing industry emerged, which has drawn a clear dividing line between corporations on one side and farmers on the other side. Both interest groups formed their own economic and commercial organisations. In the 1960s, the situation had already developed into a kind of "double-closure" (Murphy 1988) and opposite national cartels. Not surprisingly, the research and development interests of the two key actors also diverged into two different directions. The wood-processing industry was mainly interested in research and development of end products and processes inside the factories. Correspondingly, the farmers', or wood growers', interest focused on the betterment of the productivity of forests. In general, biotechnologically oriented research had a larger indent on the wood growers' side, and not so much in the corporations' side. However, the wood growers' interest in intensifying forestry's yield by biotechnological applications was not very strong. Because of the fact that Finland is rich in forests, the wood growers were mainly interested in the improvement of forestry work.

The productivity of Finnish forests was already very early defined as an issue of national survival (Kuisma 1993). The state has - beside the Finnish wood grower organisations - been active in forestry research and development. The great interest of the state in the wood-processing industry is somehow self-evident, as some forty years ago 70 percent of Finnish export came from this industry. Due to the polarised situation in the Finnish wood-processing industry, the state has placed itself into a kind of an umbrella position. It established a broader vision in which both the interests of the corporations and of the farmers can be argued.

There are three globally acting corporations in the Finnish forest industry today. The *UPM-Kymmene Group* is, measured by turnover, the biggest, *Stora Enso* is one of the world's leading forest industry companies, and *Metsä-Serla Oyj* is the sixth largest forest industry and paper-producing company in Europe. The large forest industry companies, however, seem to be less active in promoting biotechnology innovations, while companies in the chemical pulp industries, being part of the forest cluster, seem to be much more engaged in research in modern biotechnology.

The structure of the biotechnology innovation network in forest industries differs significantly from the one in the pharmaceutical industries. There are different research organisations functioning in the forepart and in the end of the production chain. The chemical pulp and paper companies and the Central Laboratory KCL co-operate in research and development of enzymes with companies like Raisio Chemicals, Primalco and Genencor International. The latter two also co-operate with VTT Biotechnology and the connected university research centres. In the forepart of the production chain, we can find actors such as The Finnish Forest Research Institute METLA that aim at improving the productivity of forests.

The Finnish Forest Research Institute (METLA), established in 1917, is an independent research organisation subordinated to the Ministry of Agriculture and Forestry. This central forest research organisation has a staff of 700 people, of whom 200 are research officers in the research centres located in Helsinki and Vantaa. METLA has additional eight research units in different parts of the country. The institute has a strong tradition in research and development activities based on traditional biotechnology. Applications of modern biotechnology have often been delayed, mainly because of the problematic proprietorship of Finnish forests. Wood production based on applications of modern biotechnology could be realised much more easily in a large and market-oriented forest industry than under the conditions of disintegrated forest smallholding. Despite these difficulties, six modern biotechnological, forest genetic research projects are currently conducted at METLA.

For corporations, the above-mentioned Central Laboratory KCL, which concentrates on the quality control of the end products of chemical pulp and paper industry mills, has recently been the most interesting co-operation partner. Lately the interest of the laboratory has broadened from mere quality control to larger R&D activities, including also research in biotechnology. The state research organisation, the Technical Research Centre of Finland (VTT) with its biotechnological laboratory is another important actor that has close linkages to corporations. Although most of the biotechnology projects of METLA, VTT and other institutional actors are financed by the Wood Wisdom Programme[7], research support for modern biotechnology is rather limited.

The radical changes at the beginning of 1990s broke the customary notion of the juxtaposition of wood-processing corporations and wood grower organisations. In the new atmosphere, the relevant actors started to consider the wood-processing industries as an uninterrupted idea-innovation chain from forestry to consumption. According to the Technology Development Centre of Finland, the greatest future challenge for the wood-processing industry is "to integrate forest economy and forest research to a constant part of the research of products of wood-processing industries. This means comprehension and governance of the linkages between the wood raw material quality and the end product quality" (TEKES 1998). Research in the Bio and Food Technology Unit of the Technical Research Centre of Finland goes in this direction; it applies biotechnology in the wood-processing industry in several research and development projects. The research on wood material, for example, aims at increasing biological stability and hindering the dyeing of the raw material.

[7] The Wood Wisdom Programme is part of the Finnish cluster programme (see e.g. Pentikäinen 2000).

4. CONCLUSIONS

Biotechnology industries have only played a minor role in the Finnish industry until today. However, the state and state-owned institutes have started to invest heavily in biotechnological research projects as well as in education and research infrastructure. There is still little R&D coming from the private sector so far, and only few business firms have started production of biotechnology based products. In Finland, like in most European countries, the leading edge of modern biotechnology is in the pharmaceutical industry. There are three main reasons for this kind of configuration. First, customers are more critical about modern biotechnological applications in food production than in drug production. This pressure from markets is the main factor in promoting 'medicinalisation'[8] of food production. Second, the knowledge of modern biotechnology is not only highly codified but it is also based on high theoretical standards. The labour force in the Finnish pharmaceutical industry is very qualified; a great number of employees have a PhD or an equal degree, which is not the situation in the agro-food industry. Third, the pharmaceutical industry has a long tradition in research and in the exploitation of scientific knowledge.

However, the leading Finnish functional food producers, Valio and Raisio, are intensifying co-operation in R&D, production, and marketing of their most advanced products. As functional food production more and more depends on clinical testing, the pharmaceutical industry and the most advanced agro-food industry may increasingly depend on the same support organisations. Such institutional overlapping may become the basis for the development of a trans-industrial co-ordinating centre for the Finnish Life Sciences business networks.

The further development of the biotechnology sector in Finland depends on whether the emerging research infrastructure will soon lead to the building up of a significant number of manufacturing plants. In overall terms, the business environment in Finland seems to be less supportive for investments in and use of biotechnology than in the USA and some other parts of Europe (Schienstock and Tulkki 2001). However, there are also some supportive factors. There seems to be widespread agreement among policy-makers that biotechnology could become a new pillar of the Finnish export sector, indicated by the massive public investment in research. Furthermore, the Finns in general are very open to technological development and their attitudes to biotechnology seem to be less negative than in other European countries. And last but not least, Finnish universities of technology are known for their openness to close co-operation with industry. The biotechnology Centres of Expertise seem to create a supportive environment for close university-industry co-operation. The massive financial support of research in biotechnology also shows some signs of success: according to the OECD (2000, 102), the growth rate of biotechnology patents in Finland in the period 1992-1999 exceeded the EU average.

There are also important factors that can hinder the further development of the biotechnology sector in Finland, however. First, there seems to be a serious shortage of highly qualified scientists in the sector, which the government is aiming to overcome by heavy investments in the education infrastructure. There is, however, huge demand for qualified engineers in the IT sector as well. Whether in the competition over human resources the biotechnology sector will be able to hold its own remains to be seen.

A major disadvantage is the smallness of the Finnish market. Therefore, companies in Finland have to be globally oriented already from the beginning. However, as some examples demonstrate, the small Finnish biotechnology companies, particularly in the agro-food and pharmaceutical sector, often lack the management capacity to establish themselves on foreign and particularly on the most important US market. On the other hand, companies operating on the national or even on the European level only may soon face serious problems because they lack sufficient awareness of and access to new biotechnological knowledge.

Concerning regulatory aspects, Finnish companies suffer the same fate as other European companies. The European regulatory framework seems to have a negative effect on the competitiveness of European companies. The greatest losers in the biotechnology age are likely to be the farmers who, for regulatory reasons, have been denied access to some products. As European farmers in general, the Finnish farmers are likely to lose global market shares to farmers from other parts of the world, who are already adopting products using biotechnology (Schienstock and Tulkki 2001).

Still another problem is the smallness of Finnish companies particularly in the agro-food and in the pharmaceutical industry. Small companies face serious problems as product innovation and improvement in operating efficiency come to depend increasingly on the use of biotechnology. In order to be able to develop the absorptive capacity necessary for applying biotechnological knowledge, companies have to set up respective research capacity. This is a major problem for small companies, as can also be demonstrated by the small amount of private R&D investment of Finnish companies in biotechnology. However, Finnish companies start to co-operate and merge not only with European but also with U.S. companies to overcome the disadvantage of being small.

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[8] 'Medicinalisation' here refers to the process in which the innovative industrial field of the pharmaceutical industries merges with the most developed innovative segments of the agro-food and other industries.

The research and development of new drugs takes about 15 years and is very expensive, costing half a billion Euro. These numbers make it very clear why the establishment of networks of small companies is not enough for constructing a modern biotechnology-based industry. According to some studies, the success of an emerging biotechnology network depends on the involvement of large, globally acting companies' (e.g. Prevezer 1998, 154; Saviotti 1998). A successful innovative biotechnology network can, in the long run, be constructed only around global companies. As the pulp and paper industry in Finland includes some global players, the sector is not confronted with this problem. As some huge mergers have already taken place in this sector, Finnish pulp and paper companies may well be able to hold their own in the biotechnology era.

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