Sectoral Variations in National Systems of Innovation

the case of telecommunication and modern biotechnology

Proefschrift

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Preface

Five years ago, immediately after graduation, Frans van Waarden proposed to get rid of the 's' in the 'drs' title. With his remark he sparked a fire that has been burning ever since. He also talked me into the project National Systems of Innovation and Networks in the Idea-Innovation Chain in Science-based Industries, and in doing so he created the opportunity to step beyond the limits of my former profession as a policymaker in community and social work. I never regretted taking this step. Now I understand how Alice must have felt in Wonderland! The talks I had with colleagues, the sincere openness I met in interviews, the stimulating work-meetings, the travels I made through Europe; even the pressure of deadlines, made it all worthwhile. It helped me to overcome the struggle with an abundant amount of information, the complexity of the subject and the solitude of the writing process. These past four years have been a most valuable experience.

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> The present order is the disorder of the future
>
> *Saint Just*

1.1 Introduction

It sometimes seems that yesterday's experience is out of fashion ever faster. Innovations follow each other at a tremendous speed. The computer you bought today -for good money- will be tomorrow's bargain, because a newer model with additional features, higher capacity and higher speed will be available. The life cycle of products is shortening and there is an overwhelming supply of new goods and services.

A sector today, which is highly subject to technological change is the telecommunication sector. However, until the 1960's the sector used to be rather stable, mainly by voice communication, more commonly known as telephony. From the mid-1960's things started to change. In the slipstream of developments in computer technology, a new kind of demand emerged. Data-communication was knocking at the telecommunications door, but was rejected several times. The analogue, voice-based telephone system had trouble in dealing with digital data-signals and could not provide the reliable kind of transmission, needed for this new kind of demand. This was the prelude to a most drastic change in telecommunications, in which the voice-based, analogue mode of transmission was replaced by a digital mode of transmission. The implications of that change have been immense, especially when telecom-engineers managed not only to digitalise the transmission signals, but also to digitalise the switching of signals. These major innovations have created a new technological platform for a range of new services, features and combinations, often sharply priced and tailored to users' demand. The most remarkable result of that development is the enormous increase of data-communication such as Internet-services and E-mail. By 1995 the total amount of data-communication was roughly 5% of all telecommunication traffic; by the turn of the century it had already increased to 50% and it is expected that by the year 2005 data-communication will amount to 95% of all telecommunication traffic (van Etten, 2000). The future expectation is that telephony will be a by-product of data-transmission.

The change from the analogue to the digital paradigm was accompanied by the introduction of optical fibres, often seen as the 'workhorse' of telecommunication. Optical transmission media enhanced the capacity of the network in such a way that even the most demanding and advanced broadband services found solid ground for further development.

> Picture this: you are watching a movie on TV and someone asks you to estimate in which year the film was released. Most probably you would look for rough time indicators like car models, fashion or perhaps a conversation referring to events that you could place in time. But since the mid 1990's there is an important new indicator. You can be pretty sure that if a cell-phone is used in the film, the date of release is after 1995. If you want to be more precise, note in addition the size of the phone. The larger the model, the older the film. Imagine, before 1995 the use of a cell-phone was a true exception.

Box I *Cell-phones as an indicator of time*

Furthermore, a whole new segment in telecommunication has truly been exploited since the mid nineteen nineties. As soon as the European countries accepted the GSM standard and liberalised the market for mobile communications, the cell-phone started its triumph march to the pockets and handbags of private users. Within months after its introduction the product was an instant success. Especially when the service-providers introduced the marketing concept of the pre-paid telephone, the larger public did not feel the barriers of high subscriber-fees and purchased this new product. Today the mobile telephone has developed into a common feature in social life and the number of subscribers is equalling the number of fixed line subscriptions.

The sweeping developments in telecommunication have drawn much attention and many scientists have started to wonder what exactly brought about the range of innovations in modern telecommunications. What precisely fuelled the process of change? Was it just technological progress, or was it the change of demand which led to the change from analogue to digital technology? And, what was the interplay between technological and societal factors which brought such dynamism in the telecommunication sector?

A similar lively innovative climate is to be found in modern biotechnology. Already in 1977 Howard and Rifkin have made predictions about future progress in modern biotechnology, but by then they were hardly believed. Who could have thought that transgenic species, animal chimaeras and clones, test-tube babies, the rental of surrogate wombs, the fabrication of human organs, and human gene surgery would have been realised before the end of the twentieth century? Most molecular biologists, politicians, journalists and scientists have rejected these predictions as 'far-fetched' and argued that this science was still light-years away. Howard and Rifkin also predicted that screening for genetic diseases would become widespread, thus raising ethical dilemmas about genetic discrimination by employers, insurance companies or schools. They expressed their concern over the increasing commercialisation of the Earth's gene pool at the hands of pharmaceutical, chemical and biotech firms, and raised questions about the potentially devastating long-term impacts of releasing genetically engineered organisms into the environment. But, again, conventional approaches among most scientists -even those working within this new field- was, that there was little need to examine the environmental, economic, social and ethical implications of what they claimed as a hypothetical future (Howard and Rifkin, 1977). In hindsight we have to admit that Howard and Rifkin have been right in most of their predictions. Innovations in modern biotechnology have been booming since the 1970's.

The dynamism and radical technological changes in modern biotechnology are only mimicked by similar radical changes in telecommunication. Who, in the 1970's, could have dreamed of the range of new services such as the Internet, mobile communication, E-mail and E-commerce? Innovativeness in biotech as well as in telecom has drawn the attention of innovation theorists, especially because there are considerable differences between countries.

Some countries clearly belong to the frontrunners in a technology and these countries often manage to gain considerably from that strategic advantage. Canada and the USA for instance have been the frontrunners in the digitalisation of telecommunication signals. The USA has been on the leading edge in telecommunication, especially regarding the development of digital equipment, the introduction of the Internet and the US has a leading position as far as the output of the ICT industry concerns. However, in other fields the US is clearly lagging behind. In mobile telecommunication the US is trailing behind, both in the production of mobile equipment as well as in the penetration of mobile cellular phones. The Scandinavian countries, especially Finland, are the 'hot spot' in this particular field of technology (Booz-Allen & Hamilton, 2000).

The USA has also developed considerable strength in virtually each sector of modern biotechnology. US farmers have already harvested genetically modified corn from several millions of acres, whereas the Netherlands is still in the stage of field trials for genetically modified crops. Nevertheless, the Netherlands has been amongst the leading European countries in modern biotechnology, although lately it lost its promising position and it is outrun by Israel, Switzerland and Finland (Ernst and Young, 1997-2001). Some countries have a persistent pattern to be on top of technology, to create new products, industries and methods, while other countries rarely create either. Some countries make radical innovations which can turn whole sectors upside-down, while others are rather to be seen as back-benchers, carefully adjusting technologies to new demands and making a more incremental kind of innovation. Countries differ in style of innovativeness.

How then, can we assess the Dutch style of innovativeness? Is the Netherlands a technology-leader, or rather a follower, and where lays its strength? What promotes the country's innovativeness, but also, what hampers it? Is it possible to change the course of developments or is a country locked in, in its historical developments? What then, are the measurement-tools that we use to evaluate the Dutch situation, and what exactly do we need to measure if we want to understand the functioning of the constituting elements of the Dutch style of innovativeness?

1.2 The state of the art in innovation research

The persistence of country-specific differences has raised the question whether technology alone can be regarded to be the single source of innovativeness. Several authors have stressed the importance of a more encompassing analysis. Van Waarden has argued that the structured interplay of institutions and organisations has an increasingly important meaning in explaining differences between countries (van Waarden, 1998, p. 3). For instance, Germany’s strength in manufacturing during the second industrial revolution could be explained on the one hand, by the organizational setup of innovative activities, but on the other by the close entanglement of industry and the education system. This interplay of organizational and institutional factors has provided the German industry a head-start, strong enough to out-perform the then leading British industry (Landes, 1969). Can it be that we need to identify similar institutional factors that explain the strength or weaknesses of the Dutch system of innovation in biotech and telecom? But then, is it enough to involve just the organizational and institutional dimension in the analysis? Should we not also take culture or the meta-institutional dimension into consideration? The meta-institutional dimension might as well have a strong impact on innovativeness, especially because it has crystallised in societal institutions and thus, influence the actor’s organizational behaviour.

The toolbox to research and analyse these questions is taken from three bodies of literature. First there is the concept of national systems of innovation, which has flourished since the mid-1980's. Then there is the notion of path dependency. Historical events have been able to cast their shadows into the future and have dominated whole trajectories of technological development, as well as institutional development. Third, there is the relative new concept of idea-innovation networks, which concentrate on how network relations in the functional phases of the idea-innovation chain contribute to the innovation process. In this introductory chapter we will briefly touch upon these three concepts; in chapter two we will discuss them in more detail.

1.2.1 National systems of innovation

The concept national systems of innovation dates from the latter half of the 1980's. The focus upon the nation-state reflects the fact that national economies differ regarding the structure of the production system and the institutional setup, but especially regarding differences in historical experience, language and culture (Lundvall, 1992, p. 13). National innovation systems comprise a multi-factor set of variables drawing on empirical findings and differences in national performances. Some of these variables are identified as generating, selecting, diffusing and supporting innovations. This especially concerns various government bodies and institutions, which are involved in shaping science and technology, and/or economic policies. Other factors to be involved in the analytic framework, are the existence and quality of academic research institutes, such as universities, public or private-funded research labs, the industry structure, the legal system of academic research, and institutions that promote technology transfer from academic research to the market (Nelson, 1993). In his pioneering research on national systems of innovation, Lundvall (1992) has proposed to include the following variables in an analysis:

– Internal organisation of the firm;
– Inter-firm relationships;
– Institutional setup of the financial sector
– Roles of the public sector;
– R&D intensity and R&D organisation

The concept of systems of innovation has provided us with a useful and promising set of analytic tools for a better understanding of innovation processes as well as the production and distribution of knowledge in the economy. It also has provided us with an appropriate framework for empirical study of innovations in their institutional context (cf. Edquist, 1997). Innovation processes are indeed influenced and facilitated by many factors. Firms do not innovate in isolation; they are entangled in various kinds of organizational, institutional and societal relations. They exchange knowledge, information and other valuable resources through market-relations, cooperation and networks. These network relations can vary considerably; some are just loosely coupled, while others build on formal agreements (Freeman, 1991). Some of these networks are set up just to solve a particular problem and will be dissolved as soon as the network has reached its solution, while others are much more stable, often to the degree of a pseudo company.

We believe that the effectiveness of (formal) networks can best be understood against the background of informal networks and informal relations. In our view, these relations provide an excellent opportunity for the exchange of (tacit) knowledge and learning. But informal networks are more than just an efficient vehicle for transferring knowledge and information into the process of innovation. They also serve as a signalling device. The actors in a network inform each other on relevant developments beyond the scope and limitation of the company. A network, especially an informal network reflects the 'mood for tomorrow', and it provides a platform to discuss what is 'in' and what is 'out', and thus helps anticipate the future and thus helps to decrease uncertainty of the actors.

Although the actors learn from cooperation processes and tend to internalise their ways of interaction and cooperation, their social and economical behaviour is embedded in the social environment. Institutions as crystallisation-points of the (meta-) institutional environment, are the signal posts for social behaviour. Institutions are the formal and informal norms, rules, habits, and convictions that regulate human behaviour. Thus, the way in which actor's operate in organisations is embedded in social and institutionalised behaviour.

It follows that these factors should be included in the analysis of a national system of innovation, because, as Archibugi and Michie have stated, 'the most fruitful lesson gained by recent research, is that technological change and innovation[1] should be explored within the social fabric in which the innovative activities are actually developed and used. The process which nurtures and disseminates technological change involves a complex web of interactions among a range of different subjects and institutions.' (Archibugi and Michie, 1997, p.122)

A good example of such a multi-factor analysis is provided by Andersen (1991) in his study of waste-water treatment in Denmark and the Netherlands. This example is all the more interesting because it not only demonstrates how organizational behaviour is embedded in the institutional environment, but also how institutions are embedded in a broader, cultural (or meta-institutional) environment in which shared values like trust, voice and exit options have developed throughout the years.

> Denmark and the Netherlands are both known for their relatively high standards in environmental care; Denmark has a system of direct regulation, whereas the Netherlands has rather relied on indirect measures, by levying taxes (the 'polluter-pays' principle). The Dutch system of regulation has led to decreasing emissions of waste-water, while the Danish system has led to a slight increase. The Dutch relative success is not simply explicable as a result of the 'polluter-pays' principle; the close cooperation between old corporate bodies[2] like the district-water-

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[1] Technological change and innovation are used here as synonyms: each technological change that reaches the market is a (product) innovation. Technological change is thus especially related to product-innovations, while the general notion of innovation can be broader, also denoting process innovations

[2] District-water-boards have existed for more than a thousand years. Water management used to be a local affair of farmers and land-owners who have built dams, dykes and dug waterways. The cooperation between local communities in regional bodies has strengthened the foundation of the district water boards in the thirteenth century (union of district-water-

boards (Waterschappen), the department of public works (Rijkswaterstaat) and the Ministry of Transport, Public Works and Water-Management has created the right conditions for innovations in this field. Holland's long tradition in dealing with water problems and a unique combination of old and new institutions have been able to make the tax system function as a clear incentive for technological change and not just as an economic burden on firms and municipalities (Andersen, cited in Johnson, 1992, p. 41).

From the above it follows that national systems of innovations have distinct characteristics which separates the system in one country from another. The embeddedness of organisations in a social, economical, institutional and cultural context provides them with distinct geographical characteristics; national, perhaps regional, or even local. The pattern of industrialisation and the notions on path-dependency have strengthened even more that the nation matters in the system of innovation, because the innovative performance of a country depends to a large extent on how actors in the system relate to each other as elements in a collective system of knowledge creation and use, as well as the technologies they use (OECD, 1997, p. 9).

1.2.2 History and path dependence

Anderson's research on the Dutch and Danish approaches in waste-water treatment has demonstrated that a careful analysis of the institutional setup should also include the study of historical backgrounds. The embeddedness of the district water boards as a corporate societal body has provided the climate of trust and mutual agreement, which has provided a solid platform for innovation. A similar argument is made by van der Ploeg when he stated that the hidden (and often neglected) power of Dutch agriculture is the degree to which producers have gained control over important resources as land, water, labour, capital, knowledge, etc.. It is not just a matter of availability of these resources, but especially who is to control the resources. Characteristic of the Dutch agricultural history is that the farming community has gained increasing control over its necessary resources, and that it has developed the skills to develop the resources in an innovative way. These hidden characteristics hold for the whole agricultural sector, as well as for individual farmers (Van de Ploeg, 1999, pp. 59-60). Also, van Iterson has argued that the origins of the Dutch collective systems of decision making are deeply rooted in the past (van Iterson, 1997, 49-61).

Our hypothesis is that today's development can often best be understood from how organisations and institutions have come into being. History matters in the analysis of innovation, because innovation-processes are often path dependent. Small events are reinforced and become crucially important through positive feedbacks (Arthur, 1994; Edquist, 1997; Pierson, 2000). History also matters because the exploitation of (natural) resources or a country's geographical condition may have caused distinct patterns of specialization. The clustering of the US car industry around the great lakes may serve as an interesting historical example. The clustering has had several historical advantages, but even though the initial advantages have faded over time, the clustering remains. The existence of natural resources may have triggered the origins of local patterns of industrial clustering, but they do not explain why industries stay in a relative small stretch of territory even if the advantage of natural resources has faded. Krugman has argued that these patterns of clustering are persistent over time, because firms value the advantage of being near other manufacturers and suppliers (Krugman, 1991, p.14). Industrial clusters provide easy exchange of knowledge, information and skills, which is an important asset in systems of innovation. The proximity of firms within the same region has a value within itself. Thus, it goes without saying that an analysis of patterns of economic activity should include history.

1.2.3 Idea-innovation networks

Hage and Hollingsworth have developed the concept of the idea-innovation chain. This concept, initially suggested as idea-innovation networks, is designed as an analytic tool, more or less analogue to

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boards, 2002).

chains of production, however, with some distinct differences. First, chains of productions are concerned with the efficiency of the firm, whereas the idea-innovation chain is concerned with the organisation of research activities through the various phases of the innovation process. Innovation is not the prerogative of the classical R&D departments, but also present in production, quality control, marketing and sales. A second difference is that chains of production move linearly from raw materials to finished products, whereas the idea-innovation chain is not necessarily based on a conception of linear sequence of innovation activities; ideas might rather bounce around and ricochet among functional arenas. The idea for a new product might start anywhere and then move back and forth within parts of the chain before a product is ready to be commercially produced (Hage and Hollingsworth, 1999). The concept of the idea-innovation chain refers to the linkages between scientific research and the industrial innovation chain. The links of the chain consist of networks involved in the various stages of the innovation process, such as basic and applied research, product-development, production, marketing and sales. This is the more relevant because it is not a given thing that a country, which is strong in a particular phase of idea-innovation chain, is also strong in the other phases. The EU for instance has pointed at the existence of the European paradox, which entails that the European strength in basic research is not reflected in its commercial success (EU, 1994). Thus, strength in basic research may go together with weakness in manufacturing, marketing and sales.

The concept of the idea-innovation chain presumes that each link in the idea-innovation chain and the strength of its networks, has its own contribution to the innovation process, which can influence both previous phases, and phases still to come. This presumes an interplay of actors within the organisation, an interplay between organisations as well as an interplay between actors in the organizational and institutional dimension. Functional departments along the idea-innovation chain are thus, not just involved in relations with other departments within the company, but also with departments of other companies, especially in pre-competitive research. We intend to analyse the structure of the organizational dimension by the key variables:

- complexity;
- differentiation;
- integration ;
- coordination;
- the strength of user/producer and supplier/producer relations;
- the firm's learning capacity.

1.3 The research problem

The national system of innovation literature, we briefly touched upon in the previous sections, has provided us with the basic framework for an analysis of the dynamics of innovation. However, the problem we have with this approach is that we think that its scope is too broad to cover sector specific characteristics. The national system of innovation-approach easily neglects that economic sectors may differ within a country. Each sector has its own organizational, institutional and even the cultural context, which are to be seen as variations of the national system of innovation. We expect to find that the dynamics in the biotech and telecommunication sector differ considerably within the national system of innovation, and the innovative performance of these sectors should therefor be understood against the background of these differences.

Several authors have already touched upon the issue of the scope of research. Some have argued that regional developments within countries have gained momentum, which has distinguished them from the general national pattern. Well-known examples of such successful regional systems are to be found in regional studies, for instance on regional innovativeness of Wales in the UK (Cooke, 1998), the Baden-Württemberg area in Germany (Heidenreich and Krauss, 1998), the Tuscany area in Italy (Ottati, 1998), the Pirkanmaa area in Finland (Schienstock, Koski and Räsänen, 1998), and in the Netherlands a good example is to be found in the regional developments study of Southeast Brabant (Boekholt and van der

Weele, 1998). The most famous -and often benchmarked- region is Silicon Valley in the USA (Saxenian, 1994). Also Castells and Hall (1994) have taken a regional perspective in their study on the making of 21st century industrial complexes. Other authors have not so much concentrated on regions, but on the dynamism within certain grand technologies (Carlsson, 1994; Sharp, 1994; Mansell, 1994; Godoe, 2000). Their view is that several technologies have a dynamism of their own, reaching beyond national borders. Ohmae (1996) has developed a similar kind of argument in stating that the dynamics of an economy are not so much influenced by nation state, as well as by regional dynamics. However, in this view regions are much broader than limited geographic areas within a country and they can even reach beyond the limits of national borders.

Yet, none of these approaches has the specificity to identify sectoral differences within national systems of innovation, even though these differences might have great relevance for the understanding of the innovative performance within sectors. Take for instance a country with a high score on the indicator openness towards new technologies. This indicator shows that there are no or only few thresholds for the introduction of new technologies. This can be the case in general, but there may be strong differences between technological sectors. The general public has embraced the novelty of mobile telecommunication, but it rejected the introduction of novel foods. In the case of biotechnology there are numerous examples where public resistance has been such that companies have refrained from stepping in this particular field. Thus, what is embraced in one, may be rejected in other sectors.

Next to public resistance, there may be numerous other issues why sectors diverge from general findings. Regulation systems may support or hamper innovation. Lack of clarity over future-directions in government policy, vagueness or even conflicting policies of Ministries involved, may differ between sectors and shy-off entrepreneurs to start up new companies. Furthermore, does each sector have the necessary resources for keeping the knowledge system up-to-date? Does each sector have sufficient levels of education, enough students to fill the future-vacancies? How, are the various levels of education interlocked within the education system, and do they serve the need of the economical sector? Questions can also be posed regarding the nature of the research system. What is the general outline of the research system? Is research predominantly performed by the industry, is it publicly funded or is it a combination of private and public research-funding? But, more interesting, do we find the same pattern in each economical sector? How does that influence the cooperation between actors in research and development in that sector? More general, how have trust-relations developed in the various fields, and are there differences between sectors?

Posing the question is already part of the answer. On a relatively simple indicator as openness toward new technologies it is plausible to find differences between sectors. If these differences, and that is the subject of the study, are indeed to be found between sectors within a country, one can raise the question whether the prevailing scope of the systems of innovation literature (nation, region or technology field), provides a good enough perspective for the analysis of the system of innovation in sectors within the same country?

We believe that these approaches provide a good starting point for further research and that they provide a good toolbox to get a good insight in the peculiarities of the sectors. However, we believe that the scope of these approaches is not precise enough to explain differences between economical sectors.

The system of innovation research, especially the national system of innovation literature has highlighted that the patterns of social and economical behaviour are embedded in the institutional structure of a country. The institutional structure shapes the general outlines and frames of reference for social behaviour, but within these broad frameworks we expect to find sectoral differences. Within the national institutional structure, we expect to find a sectoral institutional structure which may significantly diverge from the general pattern. That is why we propose an additional scope to the system of innovation research: a national- sectoral scope. The institutional setup of a nation is an important dimension to identify the broad and general peculiarities of a country, but within this institutional framework we will focus on the sector-specific characteristics. We believe that the way in which a sector has developed throughout the years determines the basic concepts, the capacity, and the sense of direction, of how to perceive a shift in the technological paradigm and how to react to it.

In our view, the concept of national-sectoral approach is better equipped to catch the dynamism of each sector than the national system of innovation approach. The latter approach might easily become too static, because it builds on the average of many economical sectors, but neglects the exceptions as they are to be found in the various economic sectors. We believe that the organisation of innovation activities, and the interplay between organisations and institutions can best be captured in a sectoral approach. We expect to find that change within sectors is stronger than change in nations. These changes do usually not take place overnight, and for the outside-observer they may exhibit endurance and stability over time. However, underneath the surface there may be a constant, gradual process of adjustment and adaptation to changing economical and institutional circumstances. As a consequence, an analysis always provides a snapshot, with relevance limited in time. However, if we include an analysis of how a system has come into being, the eloquence and dynamism, even of a snapshot, may be surprisingly high.

In this study we will discuss two high-tech sectors; telecommunication and modern biotechnology. Both sectors are among the top-innovative clusters in the Dutch economy. The table opposite gives an overview of the specialization pattern in the Netherlands, based on the number of patents in the various sectors (IPC clusters[3]).

It clearly shows that the Netherlands is particularly strong in foodstuffs, agriculture and the combination of electronics and telecommunica-tions. It also shows that the Netherlands has a good performance in miscellaneous technologies, which are grouped together under the heading of 'other technologies'.

What binds the sectors is their high degree of innovativeness and the important role of science in the generation of knowledge. What furthermore binds them, is that both technologies have undergone considerable technological change in recent years, which might have had a great impact on the organisation of research activities, as well as on the institutional and cultural resources. Conversely, the prevailing institutional conditions may have affected how the sector has adjusted to this change. To assess this research problem, we will not just discuss differences between the two sectors, but also follow developments over time, to find out what changes have taken place and under which conditions

Rank of top-five fields of specialization in the Netherlands	
IPC classes	**Indexes of specialization**
Foodstuffs	3.24
Other technologies	2.02
Agriculture	1.97
Electronics/ Telecom	1.97
IT instruments	1.58

Table 1 *Fields of specialization based on Dutch patents granted in the US, 1981-87 Source: Archibugi and Pianta, 1992*

1.4 Research questions

Our aim is to extend the system of innovation literature with a national-**sectoral** perspective by a careful analysis of two science-based industries in the Netherlands: telecommunication and biotechnology. In the analysis we will use the research-instruments from three different tool-boxes. First there is the systems of innovation-toolbox, which focuses on the organisation of the firm and inter-firm relationships, the institutional environment (especially regulations, finance, flow of knowledge between economical and institutional actors), and R&D intensity and R&D organisation. From the toolbox of path dependence we will take our interest in the historical developments that have shaped the sectors as we find them today. From the toolbox of idea-innovation networks we will take our interest in inter- and intra-firm relationships

[3] An inventor can protect his/her invention by filing a patent at national or international patent offices. If the patent is granted, it provides a temporal monopoly for the inventor to exploit the product . All possible products are categorised in the International Patent Classification system (IPC), which provides a system of definitions for each product (-group)

(focussing on complexity, differentiation, integration and coordination of research efforts), the strength of user/producer and supplier/producer relations, and the actors' learning capacity.

Our research questions are:

A_1 What are the **typical features** of the national-sectoral system of innovation in Dutch telecommunication and biotechnology, regarding:
- The technology involved;
- The organizational architecture of the idea-innovation chain;
- The institutional environment;
- The sectoral patterns of specialization?

A_2 Is there any **systematic coherence** between the characteristics of the system?

A_3 To what extent is the **pattern of specialization maintained** by the organizational and institutional elements of the national-sectoral system of innovation?

A_4 How have the **sectors reacted to radical change**, especially in their future specialization pattern, the organisation of the idea-innovation chain and the institutional environment?

A_5 Do national-sectoral systems **exist** and **do they matter**?

1.5 Research approach and methodology

Theorising on innovation-theories and research on the dynamism of innovation-activities is usually a field played by economists. It often seems that their ultimate goal is to 'catch' the innovation process in a formal model. However, the approach taken in this research-project is much broader; it is rather to be seen as a crossover between disciplines such as sociology, political science, history, economy and even social-psychology, than an exclusive attempt to find explanations within a single discipline. It is rather an attempt to integrate disciplines in order to provide a richer portrait of the innovation activities in the sectors under review. The focal point for this research project is two-fold First to find out if differences exist between economical sectors, and second, to find out how these variations have developed over time.

The basis for this study is formed by a large amount of documents and literature that was gathered in the project National Systems and Innovations and Networks in the Idea-Innovation Chain in Science-based Industries (the TSER-NIS project). This EU-funded projects has entailed a four-country comparison[4] on how the larger institutional contexts, in which science-based industries are embedded, have influenced their capacity to innovate, in particular, regarding the network-structure in innovation activities (van Waarden, 1998).

The historical dimension is mainly surveyed by using secondary literature, data and documents. This body of documents and literature has allowed the project-group to reconstruct the idea-innovation chain in the two sectors before the change of the technological paradigm took place. For a reconstruction of the developments after the change of the technological paradigm, the group has again relied on documents, reports and the like. However, from secondary literature it is often hard to identify the precise relationships between actors. It is hard to 'colour' the dynamism of the innovation process, because this is a rather tacit dimension, stored in the heads and hands of the people working in the sector. Therefor we have supplemented our secondary research with information from interviews. In the course of this project we have met 52 people in 45 interviews. The structure of these interviews was basically open, leaving the interviewees the chance to tell their own stories. The 'Dutch perspective' on innovation was mainly based

[4] Four countries have participated in this project: Austria, Finland, Germany and the Netherlands. If in the course of this study the Dutch performance is compared with other countries, it will mainly concentrate on these countries

on these interviews, but was 'sharpened' by the comparison with our Austrian, Finnish and German studies in the TSER-NIS project. The Dutch perspective was furthermore 'polished' by 27 interviews we had in Austria in the context of the same TSER-NIS project. The picture of a country becomes so much richer when it is mirrored in experiences of other countries, with different cultures and institutional environments.

1.6 Structure of the book

The book will first elaborate in more detail the conceptual framework that underlies this study. Then it will introduce the most relevant technological changes that have taken place in the two sectors. Subsequently it will discuss the historical developments in the two sectors, roughly until 1975, when it became obvious that the technological paradigm in both sectors was changing. It then will discuss in greater detail the changes that have taken place in the organizational dimension in both sectors under review and it will elaborate on the changes in the institutional dimension. The book will be rounded of with a conclusion.

Chapter 2

In chapter two we will discuss the innovation concept in greater detail. Here we hook on to the initial work of Schumpeter on innovation, who stated that innovation is the process of finding out new combinations. Innovation has always been an awkward notion for classical economists. Usually they have addressed innovation as an exogenous phenomenon, whereas evolutionary economists have regarded innovation as an endogenous process. We will briefly discuss both positions in this debate. Innovations can appear in many forms, as small, incremental improvements of existing technologies, but also as radical breakthroughs. In a taxonomy of innovations we will give an outline for the various forms. We will also discuss the various steps in the innovation process and find out how these steps are especially influenced by learning processes. Here we will devote quite a bit of attention to the national systems of innovation approach, because this concept provides us with the basic toolbox. This will result in the outline of an analytic model, and discuss important elements like complexity, differentiation and specialization, cooperation, the role of networks and the role of firm-size, especially in the case of telecom and biotech. We then, will elaborate on the organizational dimension of our model, and we will furthermore pay attention to learning in innovation processes and the organisation of research activities in and between firms. Finally we will treat the institutional dimension. Here we will discuss our approach of a national-sectoral system of innovation and discuss in more detail how these approach fits in with the growing literature on different approaches in systems of innovation.

Chapter 3

In chapter three we will motivate our choice for science-driven technologies and discuss the major characteristics and changes of the technologies under review. Those who are familiar with the technological ins-and-outs of the technologies can easily skip this chapter, but for the laymen it is a brief introduction in the technological aspects. This chapter has little meaning for the analysis, because the developments described are certainly not country-specific.

Chapter 4 and 5

Chapters four and five discuss developments in telecom and biotech from a historical perspective, with each chapter covering an important time period. Chapter four is on the earliest developments. It starts in the latter half of the nineteenth century and describes the developments until World-War II. We have used the war as a demarcation line, even though we will argue that many of the post-war developments are rooted in developments that already started in the pre-war period.

Chapter five is on the post-war period that starts at the end of World-War II and ends in the latter half of the nineteen seventies, early eighties, when the technological paradigm in telecommunication and biotechnology underwent considerable change.

Chapter 6

Chapter six focuses on the change of the technological paradigm in telecommunication. It will discuss the organizational changes that have taken place since the mid-nineteen-seventies. It will discuss the technological changes, but also the changes in the regulatory environment that have enabled the telecommunication sector to develop towards a new stage, in a liberalised environment. Against the background of technological and regulatory changes we will discuss the changes in the architecture of the idea-innovation chain.

Chapter 7

While chapter six deals with telecommunications, chapter seven does so with biotechnology. However, there are some very important differences. The regulatory systems of both sectors differ substantially. The telecommunication sector has evolved from a monopoly with strong state-involvement to a privatised state, where it could develop as a 'normal' business. Regulation in telecommunication used to be extensive, but it evolved from more to less strictness In biotech however, there is an opposite development. Regulation was weak, but has been strengthened. This has posed different problems for the sector, and we will discuss how the biotech sector has reacted to the technological and regulatory changes of the nineteen seventies and eighties.

Chapter 8

In chapter eight we elaborate on how the institutional environment has developed over time. How have institutions provided the sectors with resources so that innovation activities were possible? We focus on the production and dissemination of knowledge, the system of finance and the regulatory system. The aim of this chapter is to find out how the institutional environment has provided the jump-boards or barriers to change in the organizational sector.

Chapter 9

Chapter nine returns to the research questions and integrate the findings in a conclusion.

Chapter 2: A conceptual framework

2.1 Innovations: the concept

What makes an innovation? Some say 'an invention', others say 'a good idea', while still others will come up with 'a discovery'. In this section we will explore the concept of innovation in more detail. We will introduce the concept as it was first developed by Schumpeter and then, discuss how it has developed into the connotation its has today. However, innovation is an awkward notion, difficult tu catch in formal economic models. Therefore, we will start this chapter by getting a better grip on the concept of innovation. We will discuss the two main methodological approaches in innovation research and briefly paint the perspectives of the traditional neo-classical and the new approaches developed in evolutionary economics. The latter approach argues that the innovative performance of a firm or a country depends on the interplay of organizational, institutional, but also cultural factors. It sees the innovation process as a social system, not only influenced by technological skills, but also by cultural characteristics like trust, openness, reliability.

Then we will turn to a taxonomy of innovations and discuss the range of possibilities between minor improvements, commonly addressed as incremental innovations, and radical innovations. Knowledge and learning are at the heart of innovation; researchers gain from a deeper insight in technology, but also workers in production learn how to improve production processes and add novelty to the product. Thus, innovation is not limited to research laboratories, but it involves the input of workers along the whole idea-innovation chain: researchers in basic and applied research labs, product developers, production workers, marketeers and sales-people and of course users.

Scientific progress used to be the source of the classical innovation process, but gradually the market became more important. The innovation process has changed from a technology-push model into a demand-pull model. Whereas these two models are basically linear models, whereby the output of a certain stage is used as the (sole) input for the next stage, the modern integrated innovation processes are bi-directional processes, with multiple feedback loops and these processes include inputs form scientific progress as well as from market-demand. This has truly complicated the coordination of the innovation process. We will discuss the main coordination mechanisms as they are to be found in the hierarchy of the firm, in market-relations and in networks. Firms are increasingly involved in relations with other actors, suppliers, users, but also public and private-funded research laboratories. All the actors in the innovation process are involved in a complicated web of social relations, with a complicated system of (inter-) dependencies.

Building on this notion the concept of a national system of innovation has been developed from the latter half of the 1980's. This is a holistic, interdisciplinary approach to innovations, which includes elements on an organizational, institutional and cultural level. This multi-level analysis attempts to provide an encompassing insight in the dynamism of the innovation process. Organisations are, through a multitude of links, embedded in an institutional environment and the institutional environment, in turn, is embedded in culture.

Based on these notions we will present a model for the analysis for this research project. This model includes the organizational, institutional as well as the cultural dimensions and their interdependencies. However, the relations in the organizational dimension are still left open. We expect to find different dynamism in the two sectors under review and this study aims at filling in the dynamism of the organizational dimension for telecom and modern biotech. We will discuss complexity of the relations, differentiation and specialization patterns, co-operations between actors and the dynamism of networks. Furthermore we will discuss some notions about the influence of firm size on the innovative performance.

The notion of National Systems of Innovations has had considerable attention in recent years. Parallel to it, alternative notions have been developed, using a different unit of analysis - such as the region or the industrial sector, but largely building on the conceptual framework of 'systems of innovation' approach. The sectoral approach starts from the premises that large, technological systems have a dynamism of their own. Differences between systems are not so much due to country specific elements, but they are rather included in generic technologies, which in many cases have led to the emergence of technological sectors. Others have argued that the country is too global in the analysis of innovativeness, because some regions within a country perform much better than others. Thus, the level of analysis should not be the country, but rather the region. Still others have argued that innovations should be explained from historical trajectories. Decisions taken in the past have cast their shadows into the future and their influence is still felt today.

We will end this chapter with a short summary and conclusions.

2.1.1 Discoveries, inventions but above all: new combinations

Joseph Schumpeter was known to be a admirer of the great American entrepreneurs who so radically changed the industrial landscape at the turn of the nineteenth to the twentieth century. In his initial work on innovation (1912) he postulated two types of agents at the heart of innovation activities: on the one hand exceptional individuals (heroic entrepreneurs) who, although certainly not able to foresee the future, were willing to face all the hazards and difficulties of innovations as ‘an act of the will’. On the other hand he saw a group of imitators -much more numerous than the entrepreneurs- that was merely active as routine managers and this group followed in the wake of the heroic pioneers. In his later work Schumpeter has weakened the role of the ‘heroic entrepreneur’, as he came to recognise that large companies had institutionalised innovative activities in R&D departments and thus had bureaucratised the innovation process. Nevertheless, he still believed that an engineer in a large firm could be the heroic entrepreneur in his sense of the word (Schumpeter, 1939, also Freeman, 1998, pp. 20-1)

Whereas many have conceived innovation in a narrow sense, especially meant for technical change and product innovations (Dosi et al., 1988; Nelson and Rosenberg, 1993), Schumpeter did not restrict innovations to products and he used the term innovations in a much broader sense, referring to product as well as process innovations and even organizational innovations. He defined innovations as: ‘the setting up of a new production function’ and this covers the case of a new commodity as well as a new form of organisation such as a merger, or the opening up of new markets and so on. ‘Recalling that production in the economic sense is nothing but combining productive services, we may express the same thing by saying that innovation combines factors in a new way, or that innovations consist of carrying out new combinations.’ (Schumpeter, 1939, p. 87 emphasis added). In fact Schumpeter has identified five different forms of innovations: 1) introduction of new goods; 2) introduction of a new method of production; 3) the opening of a new market; 4) the opening of a new source of supply; and 5) the carrying out of the new organisation of any industry, like for instance the creation of a monopoly position. New combinations, in whatever form, mean the competitive elimination of existing products, technologies, skills, methods etc., which is usually addressed as the process of ‘creative destruction’ (Schumpeter, 1934, pp. 65-7).

The 1993 Frascati Manual defines innovation as ‘the transformation of an idea into a marketable product or service, a new or improved manufacturing or distribution process, or a new method of social service’ (OECD, 1993). This definition largely builds on the broad definition suggested by Schumpeter, but it highlights the process-character of innovations. It is the transformation of an idea into a final product. The implication of the definition is that discoveries and inventions are often at the basis of an innovation process, but they are not quite the same. Discoveries, inventions and ideas are inputs for and innovation process. An idea of how to combine existing technology in a new combination is often the starting-point for an innovation process, when the idea is developed into a marketable product or service.

The European Commission sees innovation as: ‘the successful production, assimilation and exploitation of novelty’, but has narrowed the term down to ‘the renewal and enlargement of products and services and the associated markets; the establishment of new methods of production, supply and distribution; and the introduction of changes in management, work organisation, and the working conditions and skills of the workforce’, thus, again taking up the elements proposed by Schumpeter more than sixty years before (EC, 1995).

2.1.2 Methodological approaches towards innovations

There is little disagreement among economists on the importance of innovations for the economy. Classical economists, neo-classical economists, Keynesians and others have all accepted -in a general way-that technical innovations are extremely important for economic growth. However, they have struggled with the determinants of innovation. What exactly supports innovations and what hampers the process? What are the determinants of innovation? Is it possible to transport a successful approach from one country to another and expect the same successful outcome?

The traditional neoclassical approach to innovation is that innovation activities are motivated by maximizing profits. Neoclassical theorists have regarded the innovation process basically as a linear process, which entails that new products emerge from scientific discoveries and are marketed to enhance economic growth. Their tool-box is filled with input and output indicators, such as R&D expenditure and growth rates. However, attempts to catch innovation processes in formal models have not been successful and that, perhaps, explains why until recently, relatively few economists have studied the elements of innovation. Others have relegated innovations to a 'black box' to be opened by engineers and historians, but not by economists (Freeman, 1994). The attempts that were made to integrate innovation in formal modelling were complicated, and lacked explanatory power. Technology has been treated as 'if it was provided by God and the engineers' (Archibugi and Michie, 1998) and innovation was seen as an exogenous factor or even a residual factor. Indeed, this residual comprised all the awkward hard-to-measure elements (Cf.; Freeman, 1994).

Yet, building on Schumpeter's inheritance several authors have tried to open the 'black box' and delved into some of the important elements of innovation. The most important contributions are made under the flag of the national systems of innovation approach. This new approach, which emerged in the late 1980's, was a response to the theoretical deficit in explaining the differences in innovative performance of countries. Furthermore, this new approach was a reaction to economical changes that have taken place in the past, especially the rise of Japan in some sectors (esp. motor-vehicles and electronics).The different ways in which the Japanese organised innovation and production activities, puzzled US and European researchers, who were so much used to the hegemony of Fordist production systems. User-producer relations, supplier-manufacturer relations, industry networks and the active role of government were challenging new issues for innovation research. It was especially Freeman who analysed how the interdependence of company R&D and production, inter-sectoral relationships and government institutions generated new technologies. The main focus in his research project was on process innovations (rather than product innovations), which enabled the Japanese system of production to take the technological lead in many fields.

The Japanese model may have been an appealing example, and is often used as a benchmark, especially in management literature, but it was virtually impossible to transpose the model's success to other countries. It could not be used as a best-practice model because the variables that constituted its success were deeply rooted in the Japanese society and its cultural, social, economical and political development. This is not unique for the Japanese system; it is inherent in any social system. Van der Ploeg provides us with an example of the successful developments in agriculture. High productivity, dynamism and prosperity of the Dutch agricultural sector are often presented as the result of its structure: the size and the production potential of the farms and the institutionalised infrastructure such as education, research, information, the financial structure, the role of the agro-industry, etc. A repetition of these factors in developing countries is often used as a promising and 'logical trigger' for agricultural development in other countries, but the results have only been poor. The reason is that the relation between structure on the one hand and prosperity, productivity and the like on the other, is crucially depending on the way in which the structure has developed over time. The reason why the state agricultural advisory service has been so influential over the years is that it could rely on a solid basis of trust which has developed in the course of the past century. Thus, the creation of trust is more important than the quality of the service (van der Ploeg, 1999, pp.59-9). The embeddedness of institutions in social and cultural behaviour is crucially important.

Freeman (1994) also came to this conclusion, when he tried to summarise the most important findings of these new attempts to understand the process of innovation.

First of all, most research points strongly to the cumulative aspects of technology. In virtually all parts of the economy, and at all times, there is an on-going process of learning, searching and exploring, which has resulted in new products, new techniques, new forms of organisation and new markets. In some parts of the economy these activities might be slow, gradual and incremental, but they will still be there if we take a closer look (Lundvall, 1992, p.8). The importance of both radical and incremental innovations for growth of the economy is widely accepted. Furthermore, innovations do not only appear as the result of a single individual's work, but they rather appear as the result from multiple inputs from different sources within and outside the firm. Moreover, innovations are not to be seen as static events, because they constantly change during diffusion. This is because workers learn how to improve the product in production or customers find new applications that the innovators had not foreseen.

Second, there has been substantial research on firm specific technology accumulation. However, exogenous generated scientific knowledge -such as for instance generated in university research- still plays an important role in the creation of innovations, albeit mostly in an indirectly way, for instance in the form of young recruits with new and valuable skills and knowledge, rather than direct, in the form of scientific papers (Pavitt, 1993).

Third, the importance of interaction among economic actors and networks in innovation processes is important. The ability to develop network relationships is especially important in corporate and government strategy towards innovation, because network relations provide access to external sources of knowledge and provide channels for an easy flow of knowledge.

Fourth, next to the afore-mentioned determinants, the importance of user/producer relations cannot be overestimated. This is not only the case for contemporary users, but also for future users (cf. Lundvall, 1988, 1992),

Fifth, the degree to which research and development have been integrated in production and marketing is an important determinant of innovation.

At that stage of research (1994) it was clear that innovation is first and foremost a social process (Lundvall, 1992; Johnsson, 1992; Archibugi and Michie, 1998; Edquist, 1996; Freeman, 1998) building on the interplay of several economic actors and institutions, which are alle embedded in a social and cultural environment, thus constituting a social system. These type of social systems can be conceptualised as regularized social practices, sustained in encounters dispersed across time and space. Social systems only exist in and through the continuity of social practices, fading away in time (Giddens, 1984, p. 83). Social systems are thus 'dynamic systems', with a sense of stability, however gradually evolving over time.

2.1.3 Types of innovations: a taxonomy

The best remembered inventions of the last century usually refer to the introduction of radical new technologies -like for instance penicillin and vaccines, transistors, computers, lasers and their applications in various fields- and pioneering innovations in automobiles and aeroplanes. These inventions are usually addressed as radical innovations. Radical, not just in the sense that these innovations are totally new, but also radical in that these innovations had the capacity to outperform and outdate former technologies in one blow; the type of innovation which Schumpeter has called 'creative destruction'. However, not all innovations attract so much attention. A vast amount of innovation is hardly noticed and refers to the multitude of small improvements and adjustments in products, as well as in processes, that build on existing knowledge and experience. These smaller innovations are usually addressed as incremental innovations. Take for instance the numerous small innovations that have taken place in the paint-industry. An outsider will hardly be able to notice a difference before and after the introduction, but the characteristics, for instance of car-paints have changed considerably throughout the years. Other innovations may have a much wider impact within a certain technological field, even to the degree of a radical innovation, but are still addressed as incremental innovations. The reason is that these technologies are used within a wider context and do not bring about change in that particular field. Many examples are to be found in the automobile industry. The development of air-bags was radical in safety-device technology, but the introduction of air-bags in automobiles was rather an incremental innovation. It hardly changed the concept of motoring. Thus, this innovation had two characteristics at the same time; radical in safety-technology, but only incremental in the automobile industry. Similar examples are ABS brake systems and power steering; both pioneering innovations within their own technological fields, but only incremental when these new technologies are used within a broader concept. That makes their technological impact much smaller than for instance the radical innovations in lasers, vaccines and new concepts like the personal computer.

This is also the case with relatively minor innovations in products which are susceptible to trends and fashion. The use of new colours, fabrics and knitting in garments is indeed an innovation, but all these minor innovations are used withing the known boundaries of making clothes. They are applied in or build on an existing body of knowledge and for that reason these innovations are usually addressed as incremental or progressive innovations.

Several authors have tried to classify innovations in a more sophisticated way than just the dichotomy between radical and incremental innovations. Even though most authors have moved between the terms radical and incremental, some have used slightly different terms, like in the example opposite.

	Radical	**Progressive**	**Indispensable**
Frequency	very low	low	high/low
Investments	very large	large	medium
Research results	long term	medium term	short term
Modifications		large	minor
Implementation	long term	medium term	short term
Detail in planning	very detailed	detailed	not detailed

Table 2 *Classes and characteristics of innovations*
Source: Sarmento-Coelho, 2000

Sarmento-Coelho (2000, pp. 323-33) has listed some major characteristics of innovations, such as the frequency in which they appear; the investments needed to finance the innovation process; the time-scope of research results; the time scope of implementation; the extent to which modifications are made and the extent to which detail is needed in planning. With this listing she has distinguished between three types of innovation. As most other authors she has reserved the term radical innovations for the introduction of completely new products. We already recalled new vaccines and lasers as good examples of this type of innovations. In the chapters to come we will further discuss the case of the search for new medicines to fight hereditary diseases and it will be clear that a real breakthrough only seldom appears. These innovations demand huge investments, are only to be realised in a long-term perspective and the planning of the research process from the initial idea to a marketable product is very detailed. Progressive innovations also refer to new products and processes and often they entail large modifications in existing technologies. Sarmento-Coelho has used the introduction of the personal computer as an example of a progressive innovation, but this is not without debate. Other will present the PC as a typical case of a radical innovation. However, the PC was indeed a totally new product, but it has been built on an existing body of knowledge that was already developed and used in mainframe computers. Other examples are the Internet and mobile telecommunication. Both new technologies for private customers, but both have been built on an already existing body of knowledge. The third category is addressed as indispensable innovations. This entails a broad category of improved products and processes, such as for instance the release of a new brand, the introduction of new items in product lines, but even modification of packages (size, design, materials). The key-word is modification and improvement of existing products. Indispensable innovations include new designs and re-designs of existing products, especially in products which are susceptible to fashion and trends. The frequency in which they appear may vary: in clothing twice a year, but in automobiles the frequency is much lower. The scope in research is especially aiming at short-time implementation and the modifications often include just minor changes.

Sarmento-Coelho's system appears to be a viable system of classification, and can be used as a general rule-of-thumb, but it bears the danger of simplification. This classification system has strongly focussed on input and output factors of the innovation process, but has not revealed what is in the 'black box'.

Freeman and Perez (1988, pp. 38-66) have mainly focussed on the effects that innovations have on techno-economic sectors. As most other authors, they have distinguished between incremental and radical innovations, the former mainly being the result of problem solving in daily practice (compare Lundvall, 1992, learning by using and learning by doing), the latter as discontinuous events and usually the result of deliberate research and development efforts in enterprises, universities or (government funded) research institutes. Important in the authors' understanding of radical innovations is that these innovations have not been built on existing practice. Nylon could not have emerged from improving production processes in rayon or woolen industries, nor could nuclear energy have emerged from incremental improvements to coal-, gas- or oil-fired power stations. Radical innovations are, furthermore, unevenly distributed over sectors and over time. Freeman and Perez have not only focussed on the character of innovations, but also on their impact on techno-economic sectors. Innovations might bring about changes in the technology system, especially when they spark far-reaching changes in technology, thus affecting several branches of the economy, as well as giving rise to entirely new sectors. Changes in the technology system are based on a combination of radical and incremental organisations, together with organizational and managerial innovations affecting more than one or a few firms. The most far-reaching impacts of innovations are able to bring about changes in the techno-economic paradigm. A change of this kind may imply the emergence of many new clusters of radical and incremental innovations. A vital characteristic of this fourth, most far-reaching dimension of technical change is that it has pervasive effects throughout the economy. Not only does it bring about a range of new products, services, systems and industries, it affects virtually every branch of the economy.

Where Freeman and Perez have concentrated on the techno-economic dimensions of innovations, we find Lundvall (1992) who separated both dimensions. Some innovations, incremental in technical terms, may have a crucial impact on the economy. This is especially true when an incremental innovation is able to solve a bottleneck problem of strategic importance, as for instance was the case with the introduction of air-inflated tyres in agricultural machinery. This incremental technological innovation truly has had a major impact on the productivity in agriculture. But also the opposite might be the case, and Lundvall refers to the radical technological break-through of the Babbage version of the computer, which was obviously a radical innovation in a technological sense. However, this innovation has hardly had any influence on the economy.

		Parametric	Strategic	Structural Change
vertical integrated firms		high	considerable	low
dense networks	family based	high	low	low
	company based	high	high	low
loosely coupled networks		low	low	high

Table 3 *Firms' capacity to innovate*
Based on Robertson and Langlois, 1995

Robertson and Langlois (1995, pp. 543-562) have examined the relationship between innovation and industry/firm structure to determine whether flexibility and scope for changes vary across environments. They have concluded that the ability of various types of organizational structures to support innovation successfully, depends crucially on the scope of innovation and the relative maturity of the industries involved.

The radicalness of innovations largely depends on the competitive competences of a firm. Large, vertically integrate firms bring about different innovations than small, network-like companies do. But then again, there are so many types of networks that their ability to innovate differs too. Robertson and Langlois have classified networks, using the degree of ownership and the degree of coordination as distinguishing indicators. The most radical form of innovation is structural change, which especially appears if information from different sources is brought together in a new device or service, like for instance in semiconductors or, more recently, in bio-informatics. Innovations, taking place within known boundaries, but re-arranging capabilities in a drastic way, are addressed as strategic innovation. The change from electromechanical to digital systems in telecommunication switching systems may serve as a good example of a strategic innovation. Innovations in the world of fashion or upgrades of models, for instance in car manufacturing are known as parametric innovations. These innovations take place within a known framework of variables, basically using the same set of variables. What makes Langlois and Robertson's analysis so interesting is that they relate specific organisation-forms to certain innovation-outcomes. Not all organisations are able to bring about the same outcome. The large vertical integrated firm with its propensity to standardisation is most likely to perform well in parametric and strategic innovations, but less in structural change innovations. Tightly coupled networks, as for instance to be found in the family-based networks in Third Italy are expected to perform well in parametric innovations, while dense company-based networks, like the Japanese Keiretsu system, have the best performance in strategic innovations. Structural change in Robertson and Langlois is best fostered in loosely coupled networks where information from different areas is brought together.

Storper and Salais (1997) have characterised innovation by the nature of the product and the nature of customer's need. They distinguish innovations in standardised production systems from innovations made t o meet the specific needs of a customer. Take -as an instance of the latter- the case of a screw-propellor for a ship. Each screw is a unique piece and designed in close cooperation with the customer. This is because each customer has its own preferences regarding speed, efficiency, power, and thrust of the vessel. The unique 'personality' of the firm depends on the extent to which it is able to combine producers' and customer's needs and interests, in a single, unique product. In contrast to

innovations used in standardised products, this is a more artisanal innovation.
Standardised innovations largely draw on codified knowledge[1], whereas knowledge in artisanal innovations is often developed by carrying out activities and heavily rely on the specific context in which a new product is developed. Artisanal innovations are merely based on a tacit type of knowledge, which is much more difficult to acquire than codified knowledge, which is rather context-independent.

The type of knowledge used in innovative activities is important, but so is complexity. Knowledge can be derived from many different fields and from many different organizational units (cf. Malerba and Orsengo, 1996). Generally the greater the degree of both sorts of complexity, the greater the need to develop effective coordination mechanisms within the firm and between key players within the industry, but also with key players in knowledge institutes.

Whitley (1998) has brought together different strains of literature in one comprehensive classification system. He has widened the scope of characteristics, not just taking into account the competences of certain types of organisation, but also taking uncertainty on the expectations of the customers and uncertainty about the nature of the innovation as important factors. He has also focussed on the differentiation in product quality, the nature of the knowledge involved in the innovation process, the complexity of knowledge, and on the organizational competences to implement innovations. He, thus, has widened the scope of characteristics, reaching beyond the dichotomy of radical versus incremental innovations.
Using these characteristics, Whitley has distinguished between five types of innovations:

1 Parametric innovations are organised around relatively well known product qualities within widely understood frameworks, as for instance the fashion industry. This type of innovation is highly responsive to customers' needs and demands. In general, knowledge, is highly industry specific, mostly tacit, but relatively simple.
2 Artisanal innovations are usually closely linked to the reputation of producers, who try to develop new product qualities for a given product of extend the product for different uses. High-quality, high-reputation, and a strong orientation toward customers' need are the key words in this approach. Knowledge is mostly tacit, but is more complex than in parametric innovation
3 Adaptive innovations are usually process-innovations and try to achieve cost reduction and changes in the standardised characteristics of goods and services. Competition is dominant and enhancement of efficiency in existing routines is key. Knowledge is highly codified and has restricted variety.
4 Strategic innovations are, contrary to adaptive innovations, meant to enhance product quality. Often these innovations will lead to market restructuring, especially when previous products become outdated. Finding new markets implies considerable uncertainty about users' needs. Knowledge in strategic innovations is mostly tacit as well as codified and comes from different organizational units. Complexity is high, but variety is limited, because innovations need to be based upon existing organizational competences
5 Radical innovations are destroying existing competences, but build new ones. They often involve the establishment of new industries. Technical- and market uncertainty are very high. User-groups do not exist and the firm has to identify and reach them. As soon as an established group of users exists, the firm has to educate and learn from (potential) them. Knowledge is highly codified and variety is high.

The table below has listed the main characteristics of this classification scheme

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[1] A distinction is made between *codified* and *tacit* knowledge. *Codified knowledge* is to be found in books and can be used by anyone in virtually every context. *Tacit knowledge* is much more difficult to obtain; it is stored in the heads and hands of workers and can only be applied in a specific context. Take for instance a stone-carver. He can tell you by the sound of his hammer how the stone will break, while for an untrained outsider every tick sounds the same.

	Para-metric	Adaptive	Artisanal	Strategic	Radical
Uncertainty about the nature of the innovation	Low	Low	Low	Medium	High
Uncertainty about users of innovation	Low	Low	Limited	Considerable	High
Differentiated product qualities	High	Low	Conside-rable	Conside-rable	Varies
Enhancement of existing organizational competence	Limited	Some	High	Conside-rable	Low
Reliance on formal, codified knowledge	Low	Conside-rable	Limited	Conside-rable	High
Reliance on complex, varied knowledge base	Low	Low	Limited	Conside-rable	High

Table 4 *Main characteristics of different types of innovation,*
Source: Whitley 1998

In each of the attempts to classify the radicalness of innovations, the authors have put emphasis on specific elements. However, there is a red line across these various systems that connects all classification system, and that is the degree of change that has been brought about by the various types of innovations. With a certain caution one can map the degree of change in a graph differentiating between product changes (the vertical axis of the graph) and process changes (the horizontal axis of the graph) (cf. Debresson, 1996, p. 23).
Yet, one has to keep in mind that Freeman and Perez, but also Lundvall reach beyond the dimensions of the graph, because they do not only address technical change as such, but also economic change brought about by technical change.

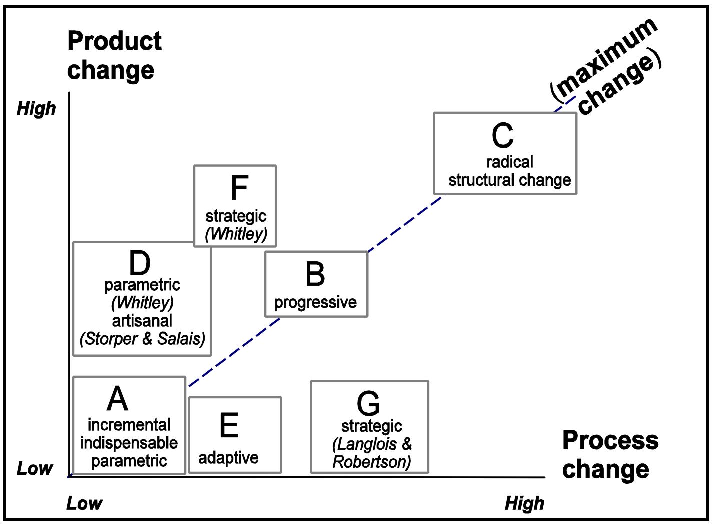

Figure 1 *Mapping change brought about by innovations*
Graph derived from Debresson, 1996

On position 'A' we find various types of incremental innovations (Freeman and Perez, Lundvall), indispensable innovations (Sarmenta-Coelho) or parametric innovations (Robertson and Langlois). On position 'B' we find Sarmenta-Coelho with progressive innovations and on position 'C' we find the bulk of what several authors have called radical innovations (Lundvall, Freeman and Perez, Sarmenta-Coelho, Whitley) or structural change (Robertson and Langlois). In addition Whitley has differentiated between product change and process change. Around position 'D' we find his definition of parametric innovations and artisanal innovations. Here we also find Storper and Salais definition of artisanal innovations. Whitley's classification of adaptive innovations, which for instance is to be found in the fashion industry, is to be found around position 'E'. Whitley's definition of strategic innovations best fits the character of product change (position 'F'), while the same term used by Robertson and Langlois better fits the description of process change (position 'G').

In this research project we are especially interested in the sectoral variations brought about by technological change in science driven technologies. Both the biotech and the telecommunication sector have indeed undergone a major technological change between 1975 and 1985. In biotechnology scientists managed to take-out strings of DNA from one organism and insert it into another to create species of a whole different nature, with 'engineered characteristics'. In the telecommunication sector the classical analogue design of signals, transmission and switching technology was replaced by digital signals and switching technology, using optical transmission. We will discuss these technological changes in more detail in the chapters still to come -especially chapter three- and we will use the notions described in this section as a template.

2.2 Determinants of the innovation process

2.2.1 Introduction

Even though it is commonly accepted that technological change is one of the primary forces generating economic growth, the causal linkages between innovation and economic growth are still not well understood. This is due in large measure to the fact that in conventional neo-classical analysis, technological change is treated as an exogenous factor (Carlsson, 1994, p. 13), provided by 'God and the engineers' as Joan Robinson once stated (Robinson cited in Archibugi and Michie, 1998, p. 1). Indeed, economic journals from the early 1950's to the late 1970's have devoted only little attention to technical change. Moreover, these studies were mainly concerned with the impact of technical change, but have hardly dealt with the determinants and sources of technical change (Ibid., 1998). One of the continuing paradoxes in economic theories has been the contrast between the general consensus that technical change is the most important source of dynamism in capitalist economies and its relative neglect in most mainstream literature. Several attempts have been made in economics, but they usually dealt with input and output factors. The 'black box' that contained the technical change process, was thought to be outside the specialised competence of most economists and had to be tackled by engineers and scientists (Freeman, 1998, p.16). Yet, there has been a change over the last two decades. Economists have to some extent tried to bridge the gap and a several articles have addressed the issue of innovation in several mainstream journals. Even politicians have lent their ear to social scientists and economists to learn from their approach in the design of science and technology policies.

The determinants of innovations are no longer exclusively sought within the domain of the natural sciences. On the contrary, innovations are increasingly studies as the process and results of the interplay between technological and societal factors, and innovation research touches upon a wide array of disciplines. In that sense innovation theory is truly 'holistic' line of research. The learning capacity of firms, for instance, is an important determinant of innovation, if not its source, but 'learning' is rather a process than a result which can be measured in quantitative, hard data. Innovation is thus, much more than the R&D process alone; it is a complex process involving technological, organizational, institutional and even cultural factors. To make things even worse, this process is under constant change, which makes it hard to pinpoint innovations as the result of one specific factor. Thus, in order to understand innovativeness, it is necessary to include institutional, organizational and political factors in the analysis, next to economic factors, because these factors are linked to and influence each other. Trying to understand innovativeness exclusively from the neoclassical analysis, for whom technology and learning are treated as exogenous determinants, might be a dead end road. An evolutionary analysis where innovative, imitative, unpredictable and change effects occur is more promising, yet not without problems. Evolutionary processes have the consequence that, through interaction with other agents and agencies, the economic environment is modified itself as well as exerting its own modifying effects. Thus, the explanatory richness of the evolutionary analysis may be larger than its neo-classic predecessor, but this approach has only limited validity. Evolutionary models need to be constantly complemented and tested against the type of historical and empirical research, which have been the hallmark of the neo-Schumpetarian tradition. In every case such research is essential since the reality which they attempt to represent is in constant flux and a unique historical process (Freeman, 1998, pp. 52-3; Cooke, 1998, p. 8).

2.2.2 Systemic character of the innovation process

Taylorism or scientific management principles were once thought to represent the only efficient way of structuring work activities. It provided the principles for the development of the ‘Fordist’ system of work organisation and control and for long this was thought to be a universal template for organising production and exchange throughout the capitalist economies. However, the competitive superiority of Fordist mass production was challenged by other systems, like ‘flexible specialization’ (Sabel, 1982, Piore and Sabel, 1984) and ‘diversified quality production’ (Streeck, 1992). These newer systems changed both the managerial ideas and the science of industrial organisation. (Kristensen, 1997; Whitley, 2000).

However, these changes have not taken place overnight. Patterns of economic development and path dependence in technological regimes have drawn the attention to the fact that historical events have a strong influence on today’s developments. The distinctive technological and institutional setup of a country for instance has produced distinct outcomes in different sectors and different societies (cf. Whitley, 1998). The drive towards new forms in the organisation of research activities is on the one hand curbed by tradition, technological and organizational rigidity and on the other hand boosted by processes like globalization, increasing complexity and increasing customer demand for high-quality/low-cost products.

The classical models of innovation were basically linear models, drawn to actors within the organisation. Initially, basic research was thought to be the inexhaustible source of ideas. A common approach was to study the technological characteristics in basic research and hand over the results to the next functional departments, one after another until the idea finally reached the market as a finished product. This model is usually addressed as the technology push model, which was later outperformed by a demand-pull model of innovation. This latter model gave customers’ demand a central position and a feedback loop was made from the marketing and sales department to product development. Despite these variations, both models of innovation were basically limited to actors within the organisation. However, the more recent models are no longer limited to actors in the organisation, but include a range of relations with actors in other organisations, but also with research institutes and other institutional actors. These latter models are usually addressed as integrated of interactive models of innovation (Rothwell, 1994), flexible models (Keegan and Turner, 1999), or improvisational models of innovation (Kamoche and Cunha, 2001). We will discuss these models in more detail in section 2.3.3.

The relations with actors outside the firm can partly be classified as market-relations, with one party acquiring something from another actor through a market-transaction. For another part these are non-market-relations, regulated by institutional and cultural elements like trust, loyalty and (the sharing of) power between the actors. A substantial amount of technology and knowledge-transfer needed for the innovation process for instance, takes place regardless of any economic incentives. Individuals imitate and learn, and know-how is often exchanged informally and voluntarily (Von Hippel, 1987). The flow of know-how may take the form of tangible as well as of intangible assets. For a firm a new tool, a machine or a new piece of equipment is a good source of innovation, but so is a scientific paper or a blue-print (Pavitt, 1994). Furthermore, these processes involve public as well as private actors. Universities, research centres and government agencies, as well as profit-seeking actors in business and industry play an important role in the fostering of technological advance (Nelson, 1987; Archibugi and Michie, 1997). The pattern of relationships and interactions that is taking place in the innovation process has a dynamism of its own, which constitutes a regular pattern of interaction. In that we can speak of a system of innovations.

It is a 'system' in that it is constituted by a number of elements and by relationships between the elements. Innovation activities are embedded in a social system and innovations are to be seen as the result of interactions between economic actors. Furthermore, it is an open system, in interaction with its environment (Cf. Lundvall, 1992, p. 2). However, it remains necessary to distinguish between 'operational' and 'conceptual' systems. An operational system refers to a real phenomenon, for instance a sequence of activities constituted in a predefined way to produce a certain outcome, or the often used example of the blood-circulation system in humans. A conceptual system on the other hand represents a logic abstraction. A conceptual system is a theoretical construct that consists of principles and rules that explain relations between and among variables. In the latter meaning, the term 'system' refers to an analytic framework, and in that, it constructs entities, but these do not represent the whole phenomenon. The conceptual framework of a system refers to the search for constituent elements and their specific characteristics, the relationships between the elements, the boundaries of this system and the interaction with the environment (cf. Cooke, 1998, pp. 2-25).

This interactive model of innovation as we find it today clearly expresses that the innovation process is not organised in an orderly, linear way of the technology-push or market-pull model of innovation. On the contrary, there are a multitude of interactions between actors in the system and actors in the environment. It shows that innovation is an ongoing process of products being modified over and over again, building on the valuable insights gained in the up- and downstream phases of the process, with information from each stage moving back and forth through the distinctive phases. The initial properties of novel products may be designed in R&D labs, but also workers in production, marketing and sales department add novelty to a product because they discover new properties or come up with smart solutions. Also, customers find out new applications. That is why the innovation process has not a clearly delimited sequence and automatic follow on, it is rather a system of interactions, of comings and goings between different players whose experience, knowledge and know-how are mutually reinforcing and cumulative (EC, 1995, p. 4).

Economic growth will only be reached if the actors involved in the innovation process can manage to gear up and attenuate their efforts in order to generate, transfer and disseminate knowledge and, furthermore, apply this knowledge in work processes. The existence of durable links, able to transmit and disseminate knowledge from the sources where knowledge is created, to the production units where knowledge is transformed into marketable products is often as important as innovativeness itself. The most fruitful lesson gained by recent research is that technological change should be explored within the social fabric in which the innovative activities are actually developed and used. Innovation is, thus, far more than just a series of isolated events shaped by enlightened inventors, looking forward entrepreneurs or dynamic co-operations. The process which nurtures and disseminates technological change involves a complex web of interactions among a range of different subjects and institutions. To understand technological change it is crucial to identify the economic, social, political and geographical context in which innovation is generated and disseminated (Archibugi and Michie, 1997, p.122).

2.2.3 National systems of innovation

The idea that actors in the innovation process are somehow linked to each other, promotes the idea of a 'system of innovation'. An understanding of the functioning of this system might possibly lead to the development of a set of tools to promote innovativeness, or help to understand why factors hamper innovativeness. The innovative performance of a firm, a sector, but also the performance of a country can be understood against this background. The performance depends to a large extend on how actors in the system relate to each other as elements of a collective system of knowledge creation and use, as well as the technologies they use (OECD, 1997, p. 9). We can speak of National Systems of Innovations, because the institutional setup of research, education and training, finance, regulation and law, differs significantly between countries.

The institutional setup is the result of processes of enculturation, which gradually has developed into a pattern of behaviour. The character of this pattern is relatively stable over time and has a large degree of predictability. On the one hand this pattern has crystallised in a relatively stable set of institutions, usually building on historical events and path dependent trajectories, on the other hand it is a system in motion, because each day adds new experiences and events, thus preventing that history will ever reach its 'final point'. Today's interactions may gradually reshape the institutional setup. Economic activities and changes are increasingly international and transactions and flows across borders tend to grow more rapidly than domestic activities. Media and information devices have speeded up communications around the globe But despite these tendencies towards increasing globalization, empirical studies of inter-firm cooperation have shown that while firms get more engaged in international networking, they reinforce domestic network relations even more (Lundvall, 1998, p. 17). Yet, the system is forged toward a new status, because people bring novelty and everyday's experience in social interactions and, thus, provide it with a sense of dynamism. This 'system in motion', has to accommodate constantly to social demands. For innovation systems this implies that they bear the characteristics of the social and institutional environment in which they are embedded. In that sense they are national systems of innovations.

The concept of National Systems of Innovation has been in the air for quite some time. Bengt Åke Lundvall used the concept of innovation systems in 1985 in a booklet on user-producer interaction to capture the relationships and interactions between R&D laboratories and technological institutes on the one hand and the production system on the other. The first widely diffused publication that introduced the concept of a national system of innovation was the analysis of Japan by Christopher Freeman. The concept 'national systems of innovation' was definitely established in the innovation literature as a result of the collaboration between Freeman, Nelson and Lundvall in the collective work on Technical Change and Economic Theory (Dosi et al., 1988; Lundvall, 1985, 1998). In general, national systems of innovations can be defined as the set of organisations, institutions and linkages for the generation, diffusion, and application of scientific and technological knowledge operating in a specific country (Galli and Teubal, 1997, p. 345). The diffusion of the concept of national systems of innovations has been remarkably fast; it is now widely used in academic circles, but also well appreciated by policy-makers who look for alternative frameworks to understand differences between economies and various ways to support technological change and innovation (cf. Edquist, 1997, pp. 1-35).

In his seminal study on national systems of innovation Nelson has assembled a number of case studies to identify the key features of the innovation systems in several countries with a high, medium and low-income countries. This collection of case studies has emphasized empirical evidence. The orientation of this project has been to carefully describe and compare and try to understand, rather than to theorize first and then to prove or calibrate the theory. (Nelson and Rosenberg, 1993, p. 4; Nelson, 1993) This study concluded that there is no single identifiable model of a national system of innovation and that, to the extent patterns could be distinguished, national systems of innovation were distinctive and essentially sui generis (Cooke, 1998, p. 2).

A national system of innovation has been defined as follows:

- "... the network of institutions in the public and private sectors, whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987)
- "... the elements and relations which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state." (Lundvall, 1992)
- "... a set of institutions whose interactions determine the innovative performance ... of national firms." (Nelson, 1993)
- "... the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country." (Patel and Pavitt, 1994)
- "... that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies." (Metcalfe, 1995)

Box 2 *A collection of definitions of National Systems of Innovation*

Lundvall's contribution has concentrated on the analytic content of the innovation system, thereby analysing the role played by users, the public sector and financial institutions. His work is an attempt to theorise about the national system of innovation concepts, with some chapters being exclusively concerned with theoretical issues. One of the aims of his book is to demonstrate the need for developing an alternative to the neo-classical economics tradition by placing interactive learning and innovation at the centre of analysis. Lundvall suggests to concentrate on the internal organisation of the enterprises; the inter-firm relationships; the role of the public sector; the institutional setup of the financial sector; and the R&D intensity and R&D organisation. These indicators might show the significant differences between countries, yet the way in which they influence the innovation process is not fully determined by these factors. Determining in detail which sub-systems and social institutions should be included, or excluded in the analysis is a task of careful historical analysis as well as theoretical considerations (Lundvall, 1992, pp. 1-19). The first steps in the development of the National Systems of Innovation concept mainly concentrated on innovation as an interactive process. Through the nineteen seventies and eighties, the linear model, in which new technology evolves from scientific efforts and thereafter materialises in nem marketable products, was discredited by empirical work. Innovation has to do with long-term relationships and close interactions with external agents. The presentation of 'the chain-linked model', by Kline and Rosenberg (1986), was important because it gave a specific form to an alternative to the linear model (Lundvall, 1998, p. 15). The second step was to realise that the relationships and interactions between agents had to involve non-market relations. These relationships were presented as 'organised markets' with elements of power, trust and loyalty (Lundvall, 1985) and presented as the conundrum of product innovations. The third step was to realise that national contexts offer different possibilities for establishing organised markets. Several studies focussed on the density of inter-firm relationships and gradually involved more national differences into the analysis, such as the interactions between universities and industry, the education and training system, the financial system, the labour market and the kind of information it fostered among specialists. These elements gradually entered into the system's perspective.

Lundvall has identified two basic approaches in the analysis of National Systems of Innovation. One line of research is building on the tradition of US science and technology studies and regards the National Systems of Innovation-concept as an incremental broadening of earlier analysis of national science systems and national technology policies. This line of research mainly concentrates on indicators of national specialization and performance regarding innovation, R&D efforts and S&T policy. Another line of research is developed by Freeman (1987) and Lundvall (1985; 1992). These studies take the fact that important parts of the knowledge base are tacit and emanate from routine-based learning-by-doing, -using and -interacting as a starting point. That is why these latter studies put a much greater emphasis on the prevailing economic structure and the country's institutional set-up (cf. Lundvall, 1998).

Thus, the concept National Systems of Innovation is not a robust, coherent theory that fully explains why some countries are more innovative that others, or have high outputs in certain technologies and low outputs in others. It is rather a set of indicators that rests on the premises that innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as the technologies they use. The linkages between firms, and the linkages between firms and knowledge institutes can take the form of joint ventures, personnel exchanges, cross-patenting, purchase of equipment and a variety of other channels (OECD, 1997, p. 9).

The National Systems of Innovation approach comprises a multi-factor set of variables drawing on empirical findings in national performances. Some of these variables are defined to support innovative activities, others to select or diffuse innovation. Depending on the nation and technology analysed in a particular case study, this set of variables can be constituted by the various government actors and institutions involved in shaping and enacting technology or economic policy: the existence and quality of academic research institutes, such as universities or public funded research labs, the industry structure, the legal system of academic research, or institutions that promote technology transfer from academic research to market (Nelson, 1993)

The concept of National Systems of Innovation has -more recently- also been adopted by the OECD and it had a project to make it operational it in more detail and the OECD has initiated several projects to collect and analyse indicators. The projects' focus is on the relation between actors and the role of networks, on clusters, and on the flow of knowledge between individuals (OECD, 1997; 2001, a,b,c). What binds the projects is that their mutual starting point is that nation-specific factors play a crucial role in innovation. On the one hand these factors relate to the organizational setup of research and innovative activities, that is, how organisations have organised innovative activities within the firm, but also how they have organised relations with actors outside the firms, such as other companies and knowledge institutes. On the other hand these factors relate to the institutional setup of a country, especially that these institutions provide sources of knowledge, finance, and skills to the innovation process. But institutions may also regulate the innovation process, for instance by favourable tax schemes. These factors might also be obstacles for the research process in that they forbid specific forms of research. A third dimension which can be most influential for the setup of a national system of innovation is history and culture. But, crucial to the definition of a national system of innovation is how these dimensions interact between each other.

> The highest union of individuals realised up to the present under the rule of law is in the state and nation. Alone and apart from his fellows the individual is weak and helpless. The greater the number of those to whom he is socially united and the more complete the union, the greater and more complete is the resulting moral and physical welfare of the individual members.
>
> *Friedrich List, cited in Hirst, 1909, p. 301*

Box 3 *List's view on national characteristics*

Although the National Systems of Innovation approach in innovation research has only started in the late 1980's, many authors have stressed that this particular country-specific

approach on innovation is tributary to Friedrich List, who challenged Adam Smith on the matter of international convergence versus path-dependence. In his book An Inquiry into the Nature and the Causes of the Wealth of Nations, Adam Smith has presented 18th century British capitalism, with its system of free trade as the best-practice model for economic development. Friedrich List on the other hand assumed that a nation's economic development was strongly dependent on its social, historical and cultural paths. Opposed to Smith, List advocated the protection of infant industries by government as well as an active state intervention to accelerate industrialisation and economic growth. For List, the state was a strong focal point in economic development and in that he was a true nationalist. The stronger the state and the closer the ties between industry and the nation, the better a country was able to compete in international competition.
(cf. Elam, 1997)

Even though the authors on National System of Innovation differ in their scope and approach and even though the system of innovation is in constant flux and hard to measure, there are some factors which are shared by all authors:

1. Innovation is understood as a process in which factors outside the firm as well as factors inside the firm are interconnected. This calls for an institutional perspective on innovation.
2. The relations that promote (or hamper) innovation are guided by country-specific regularities which constitute a structured environment, 'a system'. Unlike Schumpeter's initial assumption that innovation is caused by exogenous factors, Granovetter has introduced the notion of embeddedness, which stands for the tight web of interactions and relations that generates and promotes innovativeness.
3. A major focus in innovation research should be placed on learning process, because innovation evolves from the capacity to learn, which is influenced by factors inside and outside the firm. The learning process constitutes feed-back from the market and knowledge inputs from users.
4. Innovation is a process which builds on accumulated knowledge. Knowledge is not so easily transferable as often thought in classical economics, but rather an intangible asset, a part of a company's general stock or pool. Especially tacit knowledge is dependent on historically determined skills, experience, routines and long-term learning.
5. The role of countries has not become obsolete in a globalizing world. On the contrary, successful models cannot be so easily transferred from one country to another, because the effectiveness of systems is rooted in a country's institutional setup.

2.2.4 The need for a multi-level analysis in innovation theory

The starting point for the national system of innovation concept is that the individual actors do not operate in isolation. On the contrary, they are influenced by other actors in the innovation process through cooperation, negotiation, problem solving and the like. Actors communicate with other actors, exchange ideas, fine-tune cooperation and learn from each other. Innovation thus follows from interaction and social processes. The way how these social activities are structured among actors is of great importance. The radiation and magic of the classical models of innovation, whereby the innovation process was seen as a series of sequential steps, is totally different from the modern approaches, whereby functional departments closely cooperate with each other and with actors in the environment. Thus, the organisation of innovation activities is an important factor in the analysis of innovativeness. However, actors are not just influenced by other actors, departments or organisations. They are also influenced by the institutional and cultural environment in which they operate.

The influence of the social environment is partly felt on a conscious level, partly on an unconscious level, through a process of socialisation and enculturation. Actors are influenced by societal norms, convictions and mutual expectations. They trust that behaviour of other social actors is more or less predictable. Some norms have crystallised in is set of codified rules, which is the backbone of societal behaviour. Motor-vehicle drivers, for instance, do not decide whether to take the left or right side of the road. They are compelled to a system of traffic rules, and they know what might happen if they do not obey to the rules. They know that they endanger themselves and others, and also run the risk of punishment. In this example the grip of institutions is felt on a conscious level. The motor-vehicle driver has to learn the rules and practice driving, before s/he gets her/his driving-licence.

In general one can say that many institutional rules have a relative codified character, especially in the case that institutes, offices and agencies have a responsibility in enforcing the rules. Rules and regulations have prescribed rather detailed what is allowed and what not. The setup of the infrastructure (e.g. roads, crossings, bridges, fly-overs) facilitates furthermore that behaviour in traffic is according to the rules, and an extensive system of surveillance helps to promote proper traffic conduct. Institutions, thus, have a tight grip on social behaviour. They provide access to desirable properties through licences, permits, diplomas, certificates or quality seals and institutes enforce the rules to meet the general norms of justice and equivalence. Getting access to desired properties is usually accompanied by transaction costs.

The influence of institutions, however, is not just felt as a codified system, it is also apparent on a more tacit level in the behaviour of social groups. Everyone knows the examples of how traffic rules are ignored. The example in the text box opposite is rather extreme, but most of us know rather similar examples from their own experience. Also, in music one can find good examples. How to play an instrument is largely codified in rules. But how to master and instrument and make it sing, is a matter of practice, experience, experiment, feeling and positive feedback.

Societal ties imposed a complex, collective memory of rules, norms, values, thought and behaviour. Accordingly, innovative activities and problem solving do not take place in a random way. They are embedded in general societal notions about the nature of man, and notions about the relative importance of various ultimate values such as freedom, security, power, knowledge, health, love and beauty. This general system of values imposed the building blocks and basic criteria of distributive justice. Whose welfare should count? What is the weight of self compare to primary groups, future generations, nonhuman beings? Thus, rather than in a random way, problem solving, and innovation as a very specific way of problem solving, takes place within the coherent and relative stable context of societal belief-systems (cf. Sabatier, 1988; Sabatier and Jenkins-Smith, 1997).

Italy, and especially Naples, with its extremely busy traffic, had driven him to sheer madness. Being an experienced driver, he was used to stop his car if the signal was red. However, in Naples this was a risky kind of behaviour, because virtually all Neapolitans ignored the red light and rushed at both sides along his car. Getting acquainted to this behaviour he decided to do the same, but that again was pretty dangerous. Some of the traffic lights were not ignored, but it was absolutely obscure which ones. Only after a few days he had a slight inventory which ones to ignore and which ones to obey. Naples truly was an adventure.

Box 4 *The impact of local habits*

Actors have internalised social behaviour through a process of socialisation and enculturation. They know what they like and dislike, how to behave among peers and in public, what to cherish, and what to hate. From the first steps in Kindergarten children have learned how to cope with other children and grown-ups, how to play, cooperate and solve conflict. They have learned which behaviour is rewarding and which not. They have learned not to fight over every conflict, but to dissolve problems in a decent, rational way. They have learned a repertoire of strategies of how to reach a specific target and have learned how to choose between alternatives. They also have learned that there is something in social life which is stronger than self-interest and how to deal with authority. They know about good and bad. Social behaviour has grown on them as part of their personality in a process of enculturation.

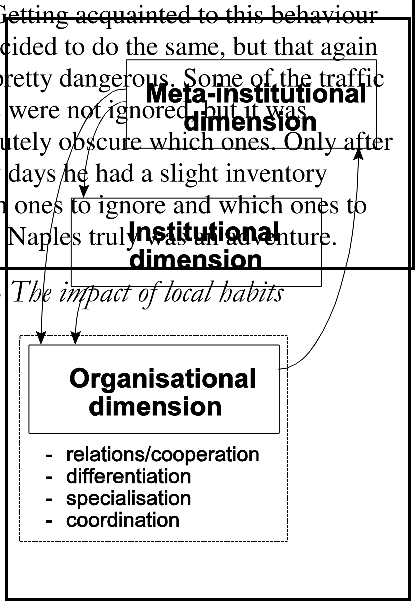

Figure 2 *Elements for a multi-level model of analysis*

With the elements discussed so far we can begin to draw the first outlines of a multi- level, analytic model that will be used to analyse the case-studies of this research project. In the previous section we have identified three important dimensions which shape the innovative behaviour of the actors in the innovation process: the organizational, the institutional and the meta-institutional dimension.

In the graph opposite we have outlined the relations between these three dimensions. The organizational dimension is influenced by the institutional environment as well as by the meta-institutional environment. The organizational environment in turn, influences the meta-institutional environment. People reconstruct culture in daily behaviour, and they also add new elements. This is a very slow process and often hardly noticed, but in the long run it leads to a gradual change of culture.

These three dimensions are thus closely interlinked into a social configuration in which the elements tend to cohere with each other, which provides the system with its dynamism. However, at the same time it puts severe constraints on the needs, preferences and choices of economic actors in the system. The elements of the social configuration are: the internal structure of corporate firms, the structured relationships among firm in the same industry on the one hand, and the firms' relationships with suppliers and users on the other; the system of research, training and education; the financial markets; the conceptions of fairness and justice held by capital and labour, the structure of the state and its policies; and society's idiosyncratic customs and traditions as well as norms, moral principles, rules, laws, and recipes for action (Hollingsworth and Boyer, 1997, pp. 2-3).

The setup of the innovation process has strongly developed during the post war years from the classical, early post-war linear models to the flexible and interactive models as we know them today. Companies increasingly cooperate in research activities, especially in pre-competitive research. Some elements of research are out-sourced to specialised research-labs which have the size and scope to provide research results at a competitive price. Furthermore, cooperation with knowledge institutes has gained importance. But what has become predominantly important are the firm's relations with users and suppliers. Thus, in the organizational dimension one can observe an increasing complexity among actors within the company (internal organizational dimensions) as well as with actors outside the company (external organizational dimensions). Actors do no longer communicate solely within their own arena, but have passed the borders between functional arenas and communicate with actors within the organisation, with members from other organisations, and with actors in the environment. Understanding the link between the institutional environment and organizational dimension of the innovation process is highly relevant for the understanding of the innovation process.

2.2.5 National systems of innovation: evaluation and critique

The concept 'national system of innovation' has provided an analytic framework to access the complicated interplay of organizational, institutional and cultural dimensions of the innovation process. It has recognised the importance of knowledge and learning in today's economic development. Investments in knowledge, in research activities, training and education, and new work processes are a key-issue in economic growth, especially in knowledge intensive sectors such as high-technology industries. The study of national systems of innovation focusses on the flow of knowledge as it is embodied in technology, but especially as it embodies in humans as human capital. The National System of Innovation analysis touches upon the generation and production of knowledge in academia, as well as the diffusion of knowledge to industry and this involves the study of the links and relations between industry, academia and government. It involves the study of the relations between industry and institutions which provide sectoral resources, like knowledge institutes, financial institutions and the system of rules and regulations. The National System of Innovation approach has provided the toolbox to analyse how ideas for innovation come from many sources and several stages of the idea-innovation chain, such as research, development, production marketing and diffusion. It has recognised that innovations can take many forms, from small increment innovations to a radical change of technology. Innovation is thus the result of complex interactions among various actors, institutions and the cultural environment in which they are embedded. The innovation process is a complicated interplay of ideas moving back and forth along the idea-innovation chain and a multitude of feedback loops has replaced the early post-war, linear models.

At the heart of the system we find the firms and the analysis focusses on the way in which the firms have organised their innovation activities. It involves the interplay of functional departments in the firm, but also the relations with other firms. It furthermore focusses on the channels by which the firms get access to external sources of knowledge and the institutional arrangement which put constraints on innovation activities. The innovative firm is seen at the heart of a complex network in which firms cooperate and compete. The network also involves close relations with suppliers and users in a multitude of cooperation forms like joint ventures, alliances and the like.

The national system of innovation approach has a policy relevance in that it can assist in pinpointing mismatches within the system and can help to identify leverage points for enhancing innovative performance and overall economic competitiveness.

The strength of the national system of innovation is rather in the narrative than in the measurement. The importance of a relation is not so much defined by the existence of that relation, but rather by the content and interplay with other relations. These are the factors that define the functioning of the system. However, these factors are difficult to measure. Thus, the national system of innovation approach is rather an analytic framework that it is a measurement tool or formal theory.

The strength of this framework is that it has identified the interplay of organizational and institutional factors and the elements that should be included in the analysis. However, the weakness of the national system of innovation approach is that it provides ‘snap-shots’ isolated in time. It easily ignores that the organizational, institutional and cultural dimensions are in a state of constant flux, which bring changes to the system. In our view a system of innovation analysis should include a long period of time, and should include an analysis of how a system has come to its present state. Countries tend to develop along technological trajectories and these are often determined by past events which have shaped the patterns of knowledge generation, accumulation and diffusion. Which path a country takes is thus largely determined by institutional and cultural factors, specific to a country.

A second point of critiques is that the national system of innovation approach is not specific enough to explain differences between sectors within a country. Within the same cultural and institutional environment, institutions might take a different trajectory of development leading to a different interplay of organisations and institutions and to a specific understanding of cultural values. One sector may for instance, be characterised by dense, integrated network relations with strong internal cohesion, but with an open attitude to the outer world. Another sector may be characterised by largely the same network characteristics, but with a closed attitude to the outer world. It is easy to see that the latter will sooner reach the limits for further development than the former. Therefore we propose to extend the national system of innovation approach (NSI) to a national-sectoral system of innovation approach (NSSI), because it will provide a better understanding of the functioning of the innovation system within economic sectors.

2.3 Towards a model for analysis

Our analytical model[2] has been built on the three dimensions identified in previous sections. The graph represents the interdependencies of the three dimensions. On the lowest level in the graph we find the organizational framework of research activities. This framework patterns the system of differentiation, co-ordination, governance and co-operation. Here we will evaluate how firms have organised innovation activities over the years and especially focus on cooperation within the functional departments of the firm and between different firms. In the discussion we will address the role of suppliers and users and the influence of firm size. Here we will also discuss the increasing complexity of the innovation process which is due to processes of specialization and differentiation. New functional departments, but also new firms have emerged throughout the years which have complicated the interactions, but also made other departments obsolete. Increasing complexity has called for new systems of coordination and governance. The capacity of traditional coordination mechanisms such as hierarchies and markets is only limited and new forms of coordination have emerged, especially in various forms of networks, such as associations, joint ventures, strategic alliances and the like. Relevant items for discussion are for instance, the number of actors, who is in and who is out, the mutual dependence of actors and the sources they have, the stability of the network and the degree of formality.

In the institutional dimension we will discuss the roles of the institutions which provide the innovation process with necessary resources. We will discuss the role of the knowledge institutes, as they provide the education and training of skilled researchers, but also in their role in the generation and diffusion of knowledge. The knowledge institutes also provide the outlines of new technologies and information about new approaches and methods. We will furthermore address the financial institutions, as they provide the funds to perform research activities, and the regulatory institutions, because they delineate the field of activity.

In the meta-institutional dimension we will discuss the influence of culture, tradition, ethics, norms and values and how these provide the innovative activities with opportunities or put constraints.

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[2] In the setup of this framework we are indebted to a the work of a research group of four European Universities, which was co-ordinated by Frans van Waarden, and in which we have participated. The project, which was funded under the TSER-programme, entailed a cross-national comparison on *national systems of innovation and networks in the idea-innovation chain in science based industries*. The analytical framework presented here, is an excerpt from that project (cf. Van Waarden et al., 1998)

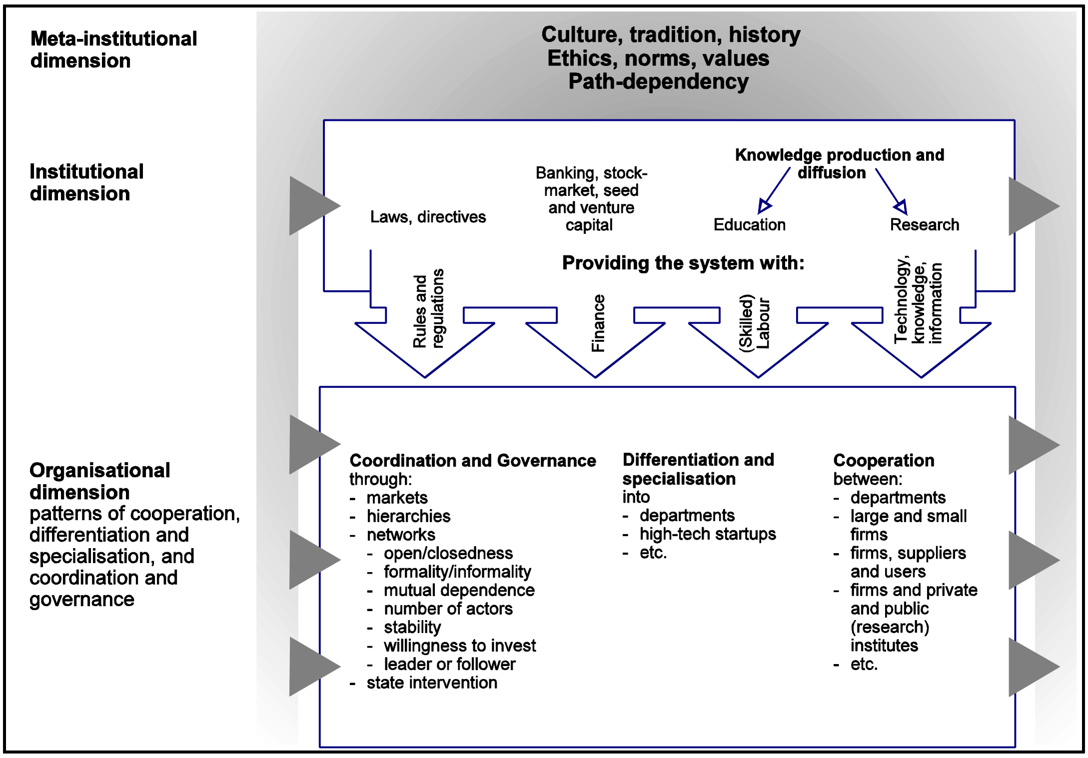


Figure 3 *The analytical framework*

We will use this analytical model to evaluate developments in the biotech and telecommunication sector and to compare both sectors. Together these three dimensions constitute the outlines for a national system of innovation with profound characteristics
It is a system in that it is constituted by a number of elements and that these elements are related to one another (Lundvall, 1992) and it is a social practice, because it is sustained in encounters, dispersed across time/space (Giddens, 1984). The organizational, institutional and meta-institutional dimensions are closely interrelated, but not in a fixed sense. The actors in the system reproduce behaviour according to the general rules of the system and thus reproduce the system itself. The intended and unintended consequences of these actions gradually push the system towards a new state. These changes appear so gradually, that they - almost unnoticed- bend the system into a certain direction, or in Giddens' words: 'repetitive activities, located in one context of time and space, have regularised consequences, unintended by those who engage in those activities, in more or less 'distant' time-space contexts. What happens in this second series of contexts then, directly or indirectly, influences the further conditions of action in the original context' (Ibid. 1984) Thus, the links in the idea-innovation system have a certain stability over time and reflect the institutional and cultural context in which they are embedded. Behaviour in the system is to a large extent predictable because the people behave like social agents.

The setup of the national institutional framework can be conceptualised as a crystallisation of culture and meta-institutions. Culture, in a broad sense, provides us with the guiding principles of right and wrong, the capacity to solve problems, the division of societal roles and in general, the rules of the game. Government, as a representation of the people, is consequently the institutional focal point of culture. It has, for instance, the authority to draw up laws, which regulate behaviour, transactions, contracting, etc., and it can impose penalties if societal actors do not behave according to the rules. Much of the rules and regulations are codified but others still remain highly tacit. Rules on credibility for instance, have several codified components (i.e. a formula to calculate an actor's financial credibility), but also several tacit components, such as a general notion of decency, trust and loyalty among economic agents. Thus, the institutional setup of financial institutions includes guiding principles for proper behaviour in financial matters. Banks, stock-market, seed- and venture capital funds are the apparent institutions/organisations. This is also the case for the system of knowledge production and diffusion. The institutional setup is designed to provide a good system of education and socialisation with the education system as its pendant, and to provide a good system of knowledge production, with universities and research institutes as the institutions/organisations. These institutions provide resources, but also restrictions to the system of innovative activities. Rules and regulations determine who, where and under what condition research can be performed and the institutional system reflects the norms, values and ethics in that field. The education and research systems provide the innovation activities with skilled personnel and knowledge, in the form of scientific principles, technologies, methods, information and skills. Thus, the setup of institutional reflects a country's system of preferences, traditions, history and norms, and the institutional dimension is embedded in cultural values.

2.4 The organizational dimension

Thus-far we have discussed the relations and links between the elements of the national-sectoral system of innovation. The arrows in the graphic representation of the model indicate the types of relation and the dependencies between the different levels. In this way we have connected the organizational, institutional and cultural dimensions. However, the graph has still left open how the elements in the organizational dimension are related to each other. We expect to find differences over time, especially induced by the shift of the technological paradigm. Furthermore we expect to find differences between economic sectors.

In the sections to come we will delve a little deeper in the organizational dimension. We will discuss the importance of knowledge and learning, especially in the context of the increasing importance of knowledge in today's economic development. Here we also discuss the increasing complexity of technologies and how these processes have affected the complexity of the idea- innovation chain and the organisation of research-activities.

2.4.1 The importance of knowledge and learning

In classical models of mainstream economics, innovation has appeared as an extraordinary event which temporarily disturbs the general equilibrium. After a process of adjustment, reflecting the work of the price mechanism, a new state of equilibrium is established. Innovation in classical economics was thus treated as an exogenous event.

In modern approaches towards capitalism however, innovation is a fundamental and inherent phenomenon. The national economies' and firms' long-term competitiveness are dependent on their capacity and competences to innovative successfully. Moreover, firms must actively engage in the innovation process in order to survive in (international and global) competition (cf. Lundvall, 1992). Knowledge is key in these processes. Yet, traditional mainstream economics has treated 'Knowledge' much the same way as it did with innovation, as an endogenous variable. Traditional mainstream economics implicitly started from the assumption, that people observe the world as it is and therefore have the same (access to) information and knowledge if they are willing to make an effort of getting the information. However, this approach towards knowledge can best be labelled as 'naive realism' (Nooteboom, 1999, p.11). Preferences, knowledge of technology and market opportunities differ considerably between people. Different people not only want different things, they also think different thoughts and have different perceptions about how to solve a problem. Thus, if people combine knowledge in new ways it is very hard to predict the possible outcomes, because the ingredients people use in innovation processes differ so much among them.

Contrary to classical, mainstream economics, where innovation and knowledge are treated as exogenous factors, in modern, evolutionary economics, innovation, knowledge and learning are treated like endogenous factors, basically building new combinations on an existing body of knowledge. Knowledge itself is at the very heart of the innovation process. Each new combination generates new insights and adds to that particular body of knowledge, which makes knowledge a cumulative asset in the innovation process. The efforts made to come to new combinations have a great variety and are difficult to compare. Some innovations are easy to reach and seemingly obvious, while others demand sustained intellectual effort to reach to new combinations, or an extremely creative mind.

In his early work Schumpeter put the entrepreneur at the heart of the innovation process, but in his later work he came to realise that innovation was bureaucratised in research laboratories. This is an important insight, because innovation was not so much depending on a 'single man's action' but rather a mixture of knowledge-generation, interaction, creativeness and learning.

Lundvall has put 'learning' at the heart of his analysis in his work on national systems of innovation. Knowledge is the most fundamental resource in the modern economy and it follows that learning (generation, accumulation and diffusion of knowledge) is the most fundamental process. Learning is a dynamic system, characterised both by positive feedback and by reproduction (Lundvall, 1992, p. 2).

Innovation is, thus basically a matter of interactions among competent actors, with learning processes and knowledge generation as its focal points. Or, as Johnson has emphasised, learning can be conceptualised as the source of technical innovation (Johnson, 1992, p. 23). Scientific activities and technical change have been brought closer together and (have) become interdependent activities. A country's capacities to innovate, cannot be detached from efforts in science, research and development. Yet, learning does not solely take place in science and R&D; it virtually takes place at every stage of the innovation process. Engineers, workers in production, and marketing and sales people are increasingly influencing the innovation-agenda.

Learning can come in many forms. Workers, who have to master routines learn from practice, from routinisation and from each other. In that process they have to face problems and find working solutions. While doing so they produce knowledge and learn how to use this knowledge in solving everyday problems. Working in production generates the skills and knowledge of how to work in the most efficient and effective way. This most simple form of building up experience involves learning-by-doing. A next stage of learning can be characterised as learning-by-using, which is especially used in more complex systems, that cannot be mastered by just improved routines. Learning-by-using goes a step further than learning-by-doing. Usually, concepts and practices are borrowed or copied from elsewhere, and adjusted to local conditions. Cooke (1998) gives the example of Japanese management skills, which were early adopted in the British industry. However, he has emphasised that the gains in efficiency and productivity were not so much achieved by copying Japanese management-skills, but rather resulted from the recognition that a more systemic change was required in the UK. A British version empowered by a Japanese success-story!

Learning-by-doing and learning-by-using usually refer to incremental types of innovations, which encompass slight improvements to existing products or routines, using known variables within a known framework, such as the parametric, adaptive and artisanal innovations in Whitley's classification system (1998). Robertson and Langlois have argued that an innovation process which involves the interaction between actors from different backgrounds, different disciplines, or with different responsibilities in the innovation process, has the capacity for new combinations. Company or family-based networks have a limited capacity to bring together different views, because their scope is limited to existing concepts, practices and routines, but loosely coupled networks, which involve different actors can bring together information from different angles and different disciplines and thus have a greater capacity to induce radical innovations. Loosely coupled networks learn-by-interacting. In his theorising on national systems of innovations, Lundvall has used the latter type of learning especially for user/producer interactions.

Still, companies increasingly go beyond this particular type of learning-by-interaction between user and producer, and organise production development in teams with members from different backgrounds, yet with equally valued skills, for example: development teams with researchers, production engineers, marketing personnel, representatives of suppliers and even user companies. Each of these is in a particular and valued position in relation to assessing how best to meet demand from markets for the product or service in question (Cooke and Morgan, 1994). The most sophisticated form of learning is to be found when networks have successfully mastered problems and become established. The successful mastering of problems, and the ability to accommodate to change over time, has given these networks a kind of maturity. It has provided them with the capacity of both strategic monitoring and continuous improvement. This is because they have the capacity to be reflexive and to apply institutional memory and intelligence in order to constantly adjust the network to the changing demands of the environment. This stage, where institutional monitoring is an embedded feature of the system, approximates what is conceived by Stiglitz (1987) as learning-by-learning (Cooke, 1998, p. 13; cf. Gibbons et al. 1994; Lash and Urry, 1994, Cooke, 1995)

Yet there is another reason why learning-processes are particularly important. They not only result in intellectual capital, but also in social capital. The latter is especially important, because the increasing importance of networks demands social skills, next to intellectual skills. By and large we can say that intellectual capital has a codified character, whereas social capital has a much more tacit character. We can locate intellectual capital in the domain of the education system, which is governed by principles of levels of learning, diplomas, grades and degrees. Social capital on the other hand is rather located in the civil society, in the relationships formed outside the formal political apparatus and the business sector. Social capital is assumed to be proportional to the density of relationships among citizens, and special weight is given to the frequency of participation in organisations outside the borders of the family (Lundvall, 1998, p.5). This is an important notion, because relations in innovation processes are on the one hand governed by similarity or complementarity of knowledge-domains, but on the other they are also governed by personal relations, built up in social clubs, student-unions and the like.

Woolcock (1998) has criticised and elaborated the concept of social capital and introduced four different elements. At the micro level he points to the need to combine strong internal cohesion (integration) with openness to the outer world (linkage). At the macro level he introduces the role of the state as a factor that can have eighter a positive or negative role in economic development. On the one hand the state needs to have strong roots in society (synergy), otherwise it will not be able to mobilise resources and/or adapt new demands that will evolve in the development process. On the other hand it is crucial that the state has an element of autonomy (organizational integrity) so that it not becomes an instrument of partial instruments.

		Organizational integrity	
		Low	High
Synergy	Low	***Anarchy*** (Collapsed state)	**Inefficiency** (Weak state)
	High	***Corruption*** (Rogue state)	***Cooperation*** (Developmental state)

Table 5 *A typology of state forms in relation to economic development*
Source: Woolcock, 1998, p. 177

Woolcock has outlined his ideas in the opposite table. The main contribution of his analysis is that it transcends the old debate about if there should be more or less state intervention. Instead he evokes a discussion of what kind of state (intervention) is needed to promote economic development. According to Woolcock the ideal developmental setup is one where on the one hand civil society characteristics combine and balance internal cohesion with openness to the outer world. A densely networked, but closed community will soon face the limits for further development. The state, on the other hand combines and balances high degrees of synergy and organizational integrity.

Building on this analysis, Lundvall (1998) has argued that the dynamic adaption of the welfare state in the smaller European countries has supported, rather than undermined, the formation of social capital at the micro level. The welfare state has embraced the development of formal and informal organisations in civil society. In a study he did with Johnson he has coined the concept of the learning economy and argued that the success of individuals, organisations, regions and countries today, does not so much reflects the knowledge that is present at a specific moment, but rather the capacity to learn. Knowledge in their view must be understood as four distinctly different kinds. Know-what refers to access to information; Know-why to causal relationships; Know-how to the capability to do things; and Know-who to the access to knowledge and capabilities of others. The former two (Know-what and know-why) are to be seen as codified variants of knowledge, while the latter two (know-how and know-who) are the more tacit variants (Lundvall, 1998; Lundvall and Johnson, 1994)

The relevance of this analysis is that it equally values explicit and tacit types of knowledge (acquisition). It also highlights the importance of informal relations in innovative networks. Innovative of economic success does not solely depend on a country's stock of codified knowledge, nor on its institutes that communicate and teach knowledge in training centres, schools and universities. These latter institutes are important because they teach students general and special skills, as well as the capability to learn in their future active life. But a second function of the education system is to install in students the basis for building social capital. It socialises students to become more or less open to interaction with others. These rather tacit elements are learned in typical social processes of interaction. Social capital is a key input to the process of formation of intellectual capital, especially for the tacit dimensions of intellectual capital, which are learned in processes that strongly resemble the master-apprentice relationships. The relevance is also in the fact that the learning capability will be high in systems where citizens are used to collaborate in civic organisations and networks, which are open to interaction with other communities and where trust is a 'natural' ingredient. Systems where citizens are focussed on narrow individual or family interests and where experts are unwilling to cooperate with experts with a different background will have increasing competitiveness problems in a globalizing learning economy (Lundvall, 1998; Lundvall and Barras, 1998).

2.4.2 Increasing technological complexity

Technological developments have boosted research and innovative activities in different areas of technology. Information and communication technology (ICT) has provided the channels to communicate knowledge around the globe. Developments in areas, such as new materials, surface technologies, optics, and microelectronics have yielded a range of new opportunities for novel products and novel production processes. Many of these new technologies are to be seen as a fusion of two or more technologies. Biotechnology and information technology for instance have integrated in bio-informatics, mechanics and electronics in mechatronics, electronics and optics in optotronics, etc. Single technologies can increasingly be applied in an ever expanding range of other technologies. For instance, surface technologies can be applied in the design of semiconductors, but also in a range of other technologies like coating of glasses, photovoltaic cells, optical fibres, sensor technology, hardening of materials, etc. It is especially information and communication technology (ICT) that has allowed for the speeding up of developments, because it has reduced transaction costs considerably.

A consequence of technological change is that the complexity of the idea-innovation links has increased. The first source of increasing complexity is in the fact that the body of knowledge has widened. If we represent the body of knowledge by a circle, then it follows that with each increase of knowledge the circle will be widened and the borders of knowledge are getting longer, and thus more difficult to encompass by single individuals. This is especially the case in high tech sectors. The second source of increasing complexity is in the fact that it takes considerable efforts to change from old technology to new technology. The rationale behind this argument is that each technology has a codified and tacit part. Codified knowledge is knowledge as it is to be found in blue-prints, in procedures and hand-books. Knowledge is codified to make it explicit and explainable. Codified knowledge allows for the diffusion of knowledge over large distances and many people. Tacit knowledge on the other hand, is knowledge that is implicit rather than explicit and it cannot be documented (yet). Nooteboom has argued that there are two conditions under which knowledge develops a tacit character. First, in the case that practice is so new and experimental that we cannot yet tell where its boundaries of application are, what different forms are available and which forms should be used in what conditions or circumstances. Second, after a practice has been developed and implemented extensively, the practice becomes routinised, as an integral part of the skill rather than explicit, codified knowledge. In this instance knowledge has developed into a 'second nature' and is no longer subject to critical reflection (Nooteboom, 1999, ch.1).

With each change of technology people have to learn a new practice, but they also have to 'un-learn' an old practice. This is especially complicated when a large part of the old technology is embodied in tacit knowledge. As it has almost developed into a second nature, it is extremely difficult for workers to see the advantages of a new technology over the old one, because people tend to stick to familiar and known concepts.

A third source of increasing complexity is the integration of several technologies in one product. Each of these technologies has its own system of idea-innovation links, and, thus, are susceptible to the processes discussed above. The integration of all these different lines of development, each with their own dynamism, demands a considerable effort.

In earlier sections we already touched upon the subject, that innovations sometimes occur as a result of scientific progress (technology push) and sometimes because of consumers' demand (market-pull). With the breakup of classical technologies into separate new technologies a whole range of technologies has developed, each with its own specialism. Some appear as the result of increasing results of new technologies (incremental innovations), and others as the joint result of developments in different technologies, combining existing technologies in new combinations. Each combination in turn allows -again- for new developments and is pushing developments into distinctly different directions. As a result, generic technologies have differentiated into several lines of development and each line has produced its own specialism. Although these separate lines of technologies stem from generic technologies, many applications have been found in adjacent field as well as in totally new fields. This is an ongoing development.

The technological developments in telecommunications may serve as a good example of this particular pattern leading to the development of new services and applications within a generic technology. The classical analogue telecommunication network was mainly used for voice communication and telegraphy. With the convergence of computer and telecommunication technologies a whole new range of services has emerged in recent years. Today the telecommunication network has to deal with leased lines, video signals, voice signals, transparent LAN services, data signals, Synchronous Digital Hierarchy, Storage Area Networks, Internet Service Providers and Application service providers. It has to be noted that these services are just a selection of applications, no doubt the future will still have more new services in stock.

Box 5 *Effects of the convergence of technologies: new fields of applications and services*

However, technology push is not the sole engine of the processes leading towards the differentiation of technologies into anew specialism. Increasing variety and differentiation has offered consumers a broad range of products to choose from and consumers have used the variety to develop distinct life-styles. Preferences have become more distinct and idiosyncratic as consumers have reached a level of prosperity that allows them to purchase those products that fit best into their life style and social profile. Nooteboom (1999, p. 47) has pointed to the paradoxical dimension of this development. On the one hand national tastes and life styles become more similar due to the ubiquitous sharing of information and recreation on TV, radio, video, film and the Internet. On the other hand, within nations there has been a movement towards ongoing individualisation. This has provided market opportunities and it is hence a motivating cause for differentiation in products (market pull). Product differentiation is enabled by technological developments and increased size of (international) markets and is motivated by individualisation of customer demand and increased competition.

2.4.3 Complexity and differentiation of the idea innovation chain

According to the definition proposed by the OECD in its Frascati Manual (1993) innovation involves the transformation of an idea into a marketable product or service. This notion separates an idea, a discovery or an invention from an innovation, and the use of the word ‘transformation’ indicates that innovation is rather a process than a single event.

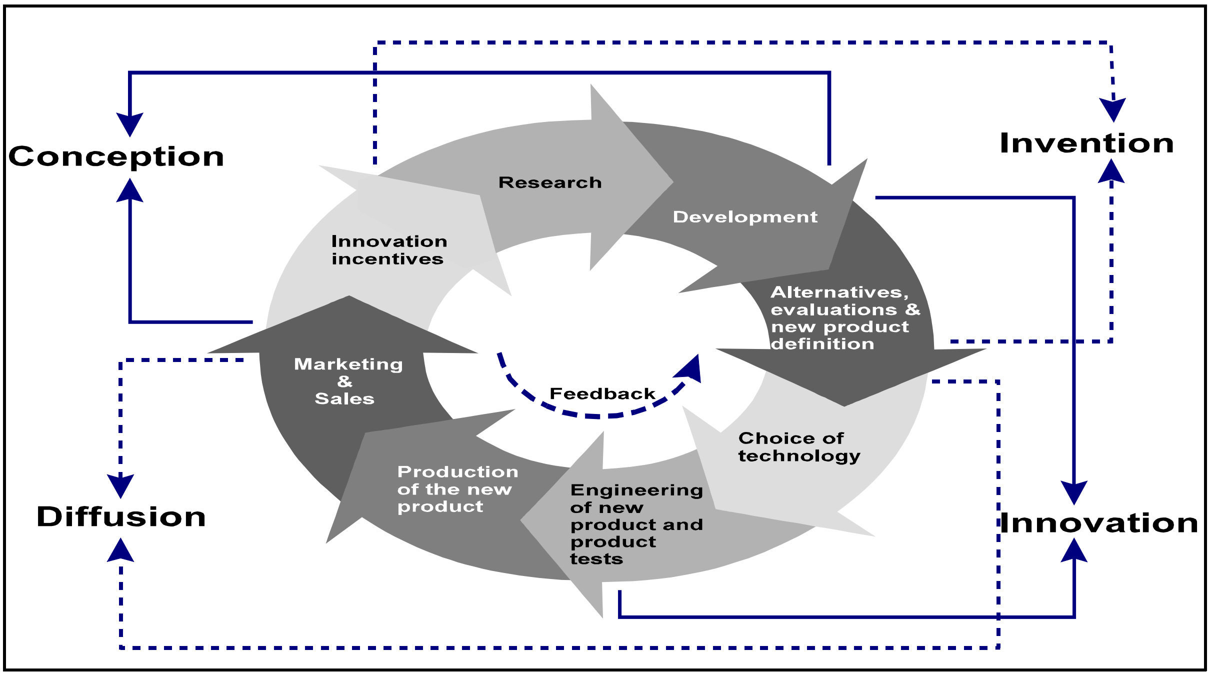


Figure 4 *The innovation Process and Technology Transfer for the Development of a New product, Good, or Service.*
Source: Sarmenta-Coelho, 2000

Sarmento-Coelho has represented the innovation process as a four-phase, circular process. She identified four phases: conception, invention, innovation and diffusion. Each of the phases has a considerable overlap with the next phase and each phase also, covers the activity of several functional arenas with distinct tasks in the process. The question whether to move from one stage into another demands a ‘go/no-go’ decision.

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

This circular model of innovation is enlightening in that it sees the innovation process as a circular movement, which connects market information to innovation incentives, thus feeding back the results of the innovation process to the initial phases of the next round. It also highlights the importance of feedback processes throughout the system.

The elegance of this model is that it clearly distinguishes between conception, invention, innovation and diffusion. The model also clearly underlines the dynamism of the innovation processes in that it is a circular movement. Yet, the model falls short in that it has limited innovation activities to a simple sequence of stages, without any links to the outside world. This is not very surprising because the setup of innovation activities has been subject to change throughout the years, and the model can be regarded as a snapshot in time.

Rothwell (1994, pp. 33-53) has argued that the innovation processes of the post war period have been related to economical changes during that period. He identified four phases in the post-war history, each with a dominant design paradigm. We will discuss these phases briefly, as stylised models.

Period 1: 1950 - mid 1960's

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

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

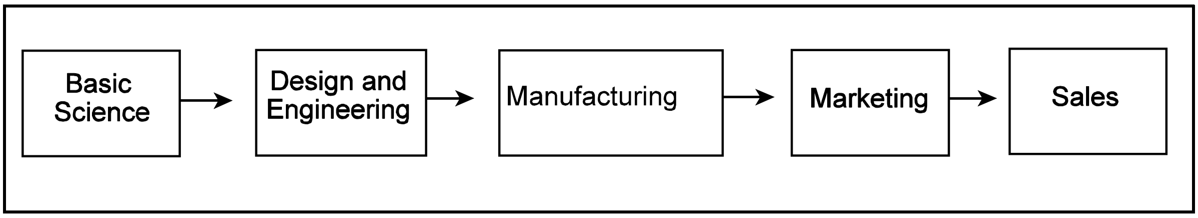


Figure 5 *Technology Push model of innovation (1950's - mid 1960's)*
Source: Rothwell, 1994

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

Period 2: mid 1960 -early 1970

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

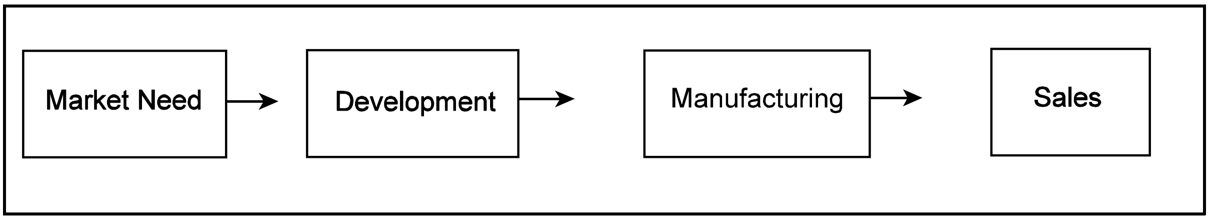


Figure 6 *Market pull model of innovation (late 1960's - early 1970)*
Source Rothwell, 1994

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

Period 3: mid 1970's - early 1980's

The 1970's have been a period of high inflation and stagnation. Demand in many technologies was saturated, especially regarding standardised products. The capacity of supply increasingly started to exceed demand. Company strategies were mainly oriented toward consolidation and rationalisation, with a strong emphasis on scale and experience curve benefits. The central strategy was cutting costs. The previous model of technology push, as well as the market-pull model of innovation were becoming redundant. The emphasis in the 1970's models was much more on the careful balance between science and technology on the one hand and the marketplace on the other. This has led to the so-called interactive or coupling models of innovation, which, according to Rothwell and Zegveld, can be regarded as a logical sequential, though not necessarily continuous, process that can be divided into a series of functionally distinct, but interacting and interdependent stages. The overall pattern of the interaction process can be thought of as a complex network of communication paths, both intra- organizational and extra-organizational, linking together the various in-house functions and linking the firm to the broader scientific and technological community and to the marketplace. In other words the process of innovation represents the confluence of technological capabilities and market needs within the framework of the innovating firm (Rothwell and Zegveld, 1985, p. 50)

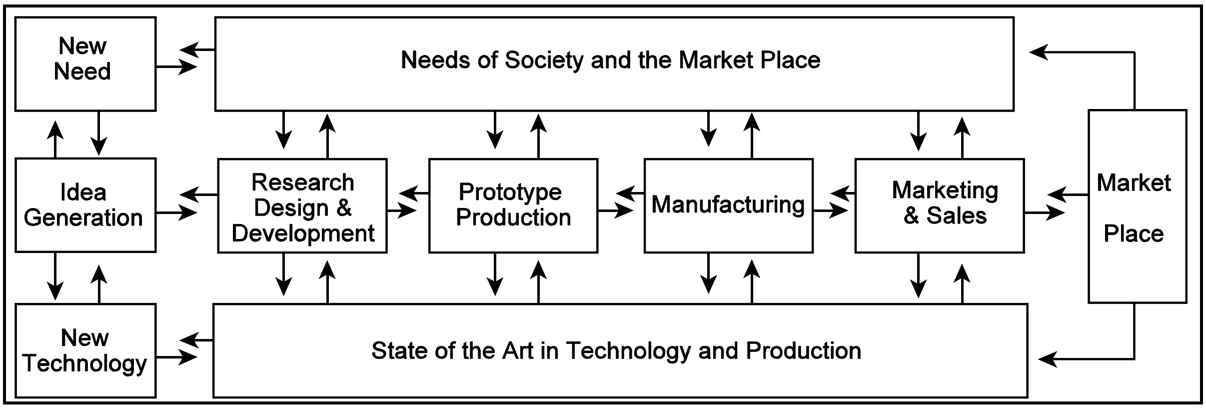


Figure 7 *Interactive or coupling model of innovation*
Source: Rothwell, 1994

Period 4: early 1980s - 1990s

The fourth period started with economical recovery, but was soon followed by recession. Firms increasingly concentrated on their core business and core technologies. This period has been marked by a growing awareness of the strategic importance of emerging generic technologies. The strategic emphasis was increasingly oriented towards technology accumulation and/or manufacturing. This period has also been marked by strong growth in the number of strategic alliances, strategic acquisitions and internationalisation of ownership and production. Furthermore, it was characterised by the major impact of new technologies and there has been a high rate of technological change. An emphasis furthermore on flexibility, product diversity and quality, and a continued emphasis on technological accumulation. Also, rapid product cycles with growing strategic emphasis on time based-strategies (just in time production and logistics). Also, increasing intra-firm activity and inter-firm integration in networks. The dominant innovation model in this period has been a further extension of the interactive and coupling model, especial regarding the changes in the sequence of activities.

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

The first new models that have broken with the purely sequential organisation of innovation are to be found in the Japanese automobile and electronics industry. In these models we find an integrated and parallel process of innovation activities, whereby researchers, managers, engineers and marketeers are all involved in the same innovation project. A core feature of this model is not only the very high level of functional overlap during the process, but also the high level of integration of the functional members of the innovation process. This model is often compared with the performance of a rugby team, whereby each player, no matter how far away from the ball, anticipates the action to come and already makes his moves in the field. This metaphor, used by Imai, Nonoka and Takeuchi (1985) clearly expresses the joint involvement of all the functional departments in the innovation process.

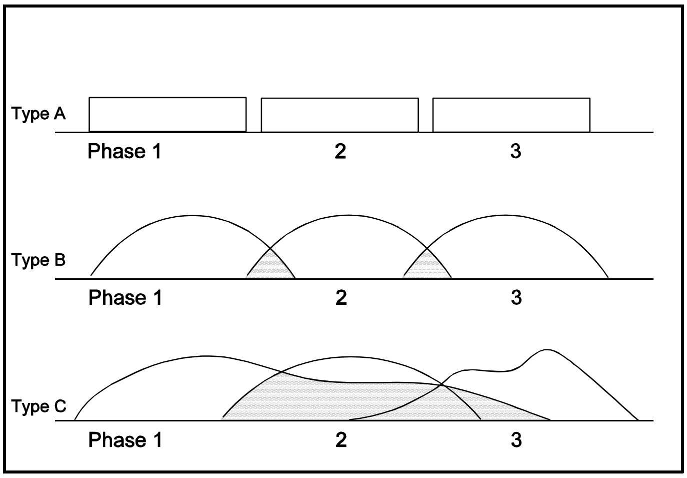


Figure 8 *Modes of innovation: Type A: sequential, Type B: overlapping, Type C: Integrated*
Source: Imai, K. et al., 1985

In the graph above this is represented by three modes of innovation. Mode A has separated the single stages as separate activities, with no mutual links whatsoever. In mode B the separate stages have slid into another and there is some overlap between the stages. This overlap, even though still small, provides the channels for an exchange of information, skills and knowledge. In mode C we find the integrated model, with communication moving back and forth between the stages of development.

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

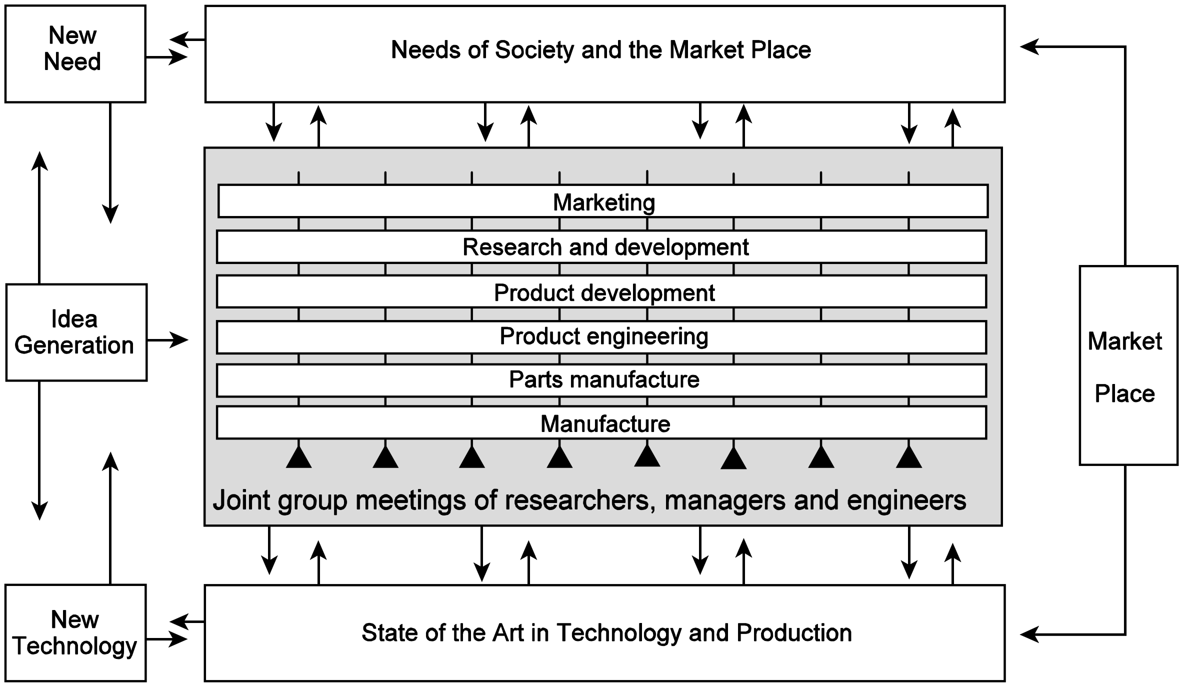


Figure 9 *An example of a parallel and integrated model of innovation. The setup of research activities in the grey box is basically parallel and highly integrated*

The innovation systems discussed so far are all basically built on the idea that the innovation process has to pass several stages before it can reach the market as a finished product or service. The Japanese setup of the innovation process has integrated the functional departments into a parallel system of innovation. Hage and Hollingsworth (2000) have reached beyond these approaches in that they suggest that innovation increasingly is taking place in idea-innovation networks. This concept, which builds on the work of Kline and Rosenberg (1986), has envisaged networks to exist at the level of an industrial sector, and each network having six different functional arenas in which various types of innovative processes occur. The functional arenas
parallel the functional stages of the idea-innovation chain[3], and start from the idea that each step of the innovation process has its own highly trained workers, dedicated research funds and specific outputs. The reason for this new approach in innovation studies is that the setup of research activities has changed in recent years. Firms increasingly concentrate on applied research and product development, while governments increasingly tend to invest in basic research activities. Furthermore, the organisation of research activities has dispersed over several sectors and several countries.

[3] The six functional research arenas are: basic research, applied research, research about product development, research on manufacturing processes, research on quality control and research about the commercialisation and marketing of products.

Rank → **↓Indicator**	**1st**	**2nd**	**3rd**	**4th**
Expenditure R&D	FI	DE	NL	AT
Patents	DE	FI	NL	AT
Citations	FI	NL	AT	DE
Survey data	DE	AT	NL	FI
Sales innovative products	DE	AT	NL	FI
Overall Performance	***DE***	***FI***	***NL***	***AT***

Table 6 *Ranking of four countries on five indicators on innovativeness*
Source, Unger, 2001

Some countries, without much basic research, have exploited the findings of basic research in other countries and have applied them in product development. This is confirmed in Unger's recent comparison of the innovative performance of four countries.
Austria for instance, ranks low on indicators as expenditure on R&D and patents. It holds a third place on the literature-based indicators and a second place on survey data. But despite these relatively low scores, it ranks second in sales, which clearly demonstrates that a country may be well equipped to commercialise innovations, without standing at the very source of the innovation (Unger, 2001, pp. 38-46). Firms may concentrate and specialise only on parts of the innovation process. This condition allowed many new high tech startups to develop strength in several niches along the idea-innovation chain. Some have especially focussed on just one specific element of the whole innovation process, or provide services to other firms engaged in the innovation process. On top of that, more and more industrial sectors are becoming research intensive and research expenditure in public as well as in private research is increasing. This has led to an extension of multi-level research networks. The challenge now is to find out how these various functional arenas are connected to each other, as knowledge is more and more differentiated in separate organisations and in separate countries (cf. Hage and Hollingsworth, 2000).

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

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

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

Kamoche and Cunha have proposed a fourth model -the improvisational model- next to the sequential, compression and flexible models of innovation. The metaphor used for this model of innovation is jazz improvisation. For an outsider jazz-improvisation easily suggests the ultimate freedom to play in whatever form, but, as Charles Mingus, the famous composer and bass-player, has stated: 'You can't improvise on nothin, man; you gotta improvise on something!' (Mingus cited in Kernfeld, 1995)

Music exists within a certain musico-structure which defines the basics for a performance like harmony, key, rhythm and tempo, theme, chordal progression, etc., which provides structure and form to the performance. Unlike most other musical forms, which rely on a tight script and/or conductor, jazz music contains only few constraints regarding style and interpretation. It uses structure in a creative way, which allows the musicians to alter the structural foundations of their playing. Within the minimal structures of consensual guidelines and agreements, the members improvise in a creative way to reach large outcomes and effective action. Improvisational freedom is, thus, only possible against the well-defined backdrop of rules and roles.

Applying jazz improvisation as a metaphor for the innovation process includes certain minimal norms, such as the nominal leader and an unspoken understanding of the need to respect and comply with the basic guidelines of behaviour. It demands a climate of constructive controversy, which fosters trust and cooperation and builds on dialogue and inquiry. Trust is an important part of this process, as a fundamental ingredient in sustaining performative interdependency and social cohesion. Trust arises as the result of comparable skills among the members as well as from the psychological buffer which helps to prevent from errors, which are inherent to the nature of experiment. Such improvisations can only be successful if there is minimal basic structure, a set of cognitively held rules for generating and building ideas. It also needs a template, a song, a chorus or a riff, which is the anchor-point for a wide stock of competences, which allow the members to try different approaches and experiments, not only within a single field of competence, but also in the experimental combination of competences from several fields. Improvisation involves a constant re-fashioning and re-interpretation of the performance in response to colleagues and the audience (cf. Kamoche and Cunha, 2001, pp. 733-764).

The models as they were presented by Sarmentha-Coelho, and especially Rothwell have a richness in describing the evolution from simple linear models to more dynamic kind of approaches. Hage and Hollingsworth have mainly concentrated on the existence of (and relations between) different dynamics in the functional arenas of the idea innovation chain. Kamoche and Cunha have developed a classification system which has integrated these approaches in a sophisticated, but elegant classification system, and we will use this classification system as a frame of reference for our research project.

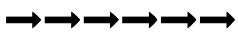
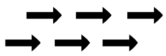
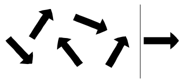
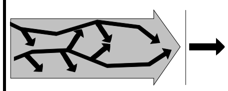
Model	***Sequential***	***Compression***	***Flexible***	***Improvisation***
Process flow				
Under-lying assump-tion	Purposive rationality and predictability in stable environments	Activities can be predetermined. Process can be adapted to the environment	Embracing change. Absorbing uncertainty	Action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

Table 7 *Key Characteristics of Product Innovation Models*
Source, Ken Kamoche and Miguel Pina e Cunha

2.4.4 Organisation and coordination of research activities

An element which has not been addressed explicitly in Kamoche and Cunha's classification system is the influence of decreasing stability of demand and technology on the organisation and coordination of innovative activities. In general, the more stable the demand and the less frequent the change in technology, the more advantageous it is for firms to organise production in large, vertically-integrated firms and to reap economies of scale by producing standardised products (Hollingsworth and Boyer, 1997, p. 25). Also Chandler (1977, 1990) has argued that social systems of mass production perform best when one or more of the following conditions are best met: (1) firms serve large and stable product markets, (2) have products and process technologies that are rather stable, (3) have a low level of innovation.

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

With the emergence of demand for more product-variations, the purely sequential model was dysfunctional, because it was a time-consuming method, unable to quickly adjust to customers' demand. The Japanese firms have understood this problem well when they sought the solution in a far reaching integration of functional departments. The sequential mode of innovation, which -by and large- mimicked the production process, was left to give rise to a more synchronised mode of innovation. The steps of the process were compressed to speed up and geared to each other. Instead of waiting until a product was finished in one department before it was handed over to the next department in line, departments started to synchronise activities. Information about the product was communicated in a much earlier phase, and the next department in line already started its activities, while the previous department had not finished its work. Thus innovation activities of different departments were geared to each other and communication increased through regular meetings, thus providing implicitly establishing several feedback loops in the process. The time to develop an idea into a marketable product was shortened considerably and the process was tailored to meet the demands of higher-speed environments. With these organizational innovations the Japanese industry was especially successful in the automobile and electronics industry, but the application of this organizational innovation was only part of the Japanese success. A second element was in the close cooperation with producers and suppliers. Major industries teamed up with privileged suppliers and innovation was a joint responsibility. However, the key to the Japanese success-story was a close cooperation of organizational units, which were, until that day, organised in a more detached and sequential mode

When high-speed environments turned into turbulent environments and with the increasing complexity of science and technology, another approach was found in the flexible and improvisation model. In response to the needs of highly dynamic markets and technologies, producers in some areas have engaged with other firms - sometimes competitors, sometimes firms in complementary industries- to produce collective goods (Hollingsworth and Boyer, 1997). Following Prahalad and Hamel (1990, pp. 81-2), Nooteboom (1999) has argued that firms have to concentrate on their core competencies to meet the demands of intensified competition, shortening product life-cycles and globalization. Firms must be able to quickly adjust to changing opportunities. Strengthening the core competences of a firm implies a strengthening of their learning capacity, especially the capacity to coordinate diverse production skills and integrate multiple streams of technologies. Concentration on core competences also implies that one needs to seek partners which supply competencies which do not belong to one's own core, but are needed as complementary to it (Porter and Fuller, 1986). The main advantage of co-operation is that it allows for more flexibility and supports novel combinations. Different partners have different perspectives. They perceive, interpret and evaluate opportunities as well as threats in different ways and partnerships have the best capacity for novel combinations. Partnerships can tap into different sources of competence, yield the advantage of economies of scale and enable to the sharing of risks. It is also advantageous to out-source activities, because fixed costs of investments are transformed into variable costs. Especially the emergence of small innovative and entrepreneurial firms has challenged the innovative capacity of the large, vertical integrated firms. The latter type of firm has recognised that the bureaucratic approach could not meet the agility of small entrepreneurial firms. Some of these large firms decided to found their own 'skunk works'; smaller, highly autonomous departments/plants that worked on specific problems outside central control with the aim of commercialising their solutions. The need for these new approaches has been accentuated by the fact that co-evolution of markets and technologies today has increased the difficulty of forecasting (Makridakis, 1990). The need to constantly rework product design in the light of new technological insight and changing circumstances has explicitly recognised that the old, prescriptive models are no longer adequate under conditions of high market volatility. The flexible and improvisational models are both change-driven, closer to 'exploration' than to 'exploitation' (March, 1991) and both models place emphasis on discovery and handling surprise. However, while flexible models stimulate variation and try to push flexibility to the maximum, the improvisation model lays more emphasis in the careful balance between structure and freedom (cf. Kamoche and Cunha, 2001).

Apparently the best suited coordination-mechanism in the case of stable technologies and stable demand are markets and hierarchies. A market can be simply defined as a social system in which individuals pursue their own welfare by exchanging things with others whenever trades are mutually beneficial. Participants in the market are in competition with each other for scarce resources; each actor tries to acquire things at the least possible costs, and to convert raw materials into more valuable things that can be sold at the highest possible price (Stone, 1997, p. 17). In the market we basically do not find durable relations among economic actors. The only purpose of markets is to make on-the-spot, coherent instantaneous transactions, without any concern about future strategies. However, markets have their limitations, because they are not always the most efficient institutional form for economic coordination. Chandler (1977; 1990) has argued that, in order to achieve lower production costs and greater economies of scale, economic actors have organised transactions in the institutional framework of a firm or a hierarchy. In this framework they can enhance efficiency, reduce transaction costs, and minimize the opportunism inherent in exchange relations (Williamson, 1975; 1985). Thus, the firm has internalised the market-process in its own hierarchy. Yet, these co-ordinating mechanisms come under severe pressure when complexity and competition increase and product life-cycle shortens. Increased complexity and all the adjacent processes that push towards more variety, more flexibility and more specialization are principally at odds with the stability that for so long has characterised the large, vertical integrated firm. The failures of Keynesian economic policies, the collapse of the East European economic blocks, but also the strains of the social democratic model, with Sweden as its shining example, have demonstrated that the efficacy of self-adjusting market mechanisms is limited. It has become evident that markets only have a limited capacity for coordination of transactions between economic actors, especially when: the quality of products is uncertain; increasing returns to scale prevail; most future contingencies are uncertain; or in the case that there is a multitude of repetitive transactions within a truly decentralised economy. Markets are thus a useful coordination-mechanism, but only under certain conditions, for instance, when transacting actors engage in decentralised, arm's-length bargaining. Here, parties are generally organised in informal, more independent relations. Parties involved in negotiating remain autonomous and each party presses his/her own interest vigorously. Contracting is relatively comprehensive (Hollingsworth and Boyer, 1998). An alternative for market coordination is coordination within the hierarchy of a firm, as we have seen in the technology-push model, whereby the hierarchy is used to enhance efficiency, reduce transaction costs, and minimise the opportunism inherent in exchange relations. Large enterprises have been the functional response to the demand of large-scale markets and capital intensive, but relatively stable technologies. The modern enterprise has thus internalised the process of conducting transactions among economic actors outside the firm (cf. Chandler, 1977, 1990).

Hollingsworth and Boyer (1998) have argued that, both markets and hierarchies are driven by the principle of self-interest. An alternative coordination mechanism may evolve from a more societal, over-arching perspective, whereby the state or communities (local, regional, ethical, scientific) put constraints on transactions among economic agents. The state is an important actor in this respect because it has the capacity to give a set of rules to regulate interactions among economic actors. This is especially relevant in the case of (near to) pure and perfect market competition, which demands codified rules of the games for coordinating economic transactions. But also smaller or more sectoral-based communities may put constraints on transactions.

Communities are to be seen as comprehensive systems of norms and values, each with its specific sets of do's and don'ts. However, contrary to state-based systems of regulation, which are usually well-codified, the constraints of smaller and sectoral communities are rather tacit. They involve strong societal values as trust, reciprocity, obligation and honesty. Between coordination principles based on self-interest (markets and hierarchies) and coordination principles based on over-arching societal principles (states and communities) we find a range of inter-firm coordination systems, such as alliances, networks, joint ventures, strategic alliances and even associations. What binds these latter types of coordination mechanisms is that the actors are neither integrated into a formal organisation, nor do they act autonomously within a market. Rather, actors are loosely tied to each other in long term relationships that ensure the capacity to cooperate and collaborate with each other through repeated exchanges.

However, these forms of cooperation also imply risk. Partners in co-operation will try to achieve and maintain maximum flexibility and a minimum risk of dependence. Hence they try to share a minimum in specific investments and a maximum in joint value added, while maximizing joint added value as a whole. In cooperation projects -in whatever form- firms have to find a careful balance between cooperation and competition. The main drive towards alliances is the need to cooperate in order to maintain flexibility, core competences and the incentives that arise from autonomy, while utilising complementary resources for both efficiency and learning (Nooteboom, 1999, p.49).

2.4.5 Networks

The innovation process is only rarely confined within the boundaries of individual firms, because it is a very complex and most uncertain activity. Successful innovations usually require the combination of inputs from multiple sources, like other firms, specialized research organisations, and universities. Also, suppliers, users and competitors are often involved in innovation processes. Collaboration is understood as any activity where two or more partners contribute differential resources and knowledge to agreed complementary aims (Dodgeson, 1994, p. 285) and such collaborations are expected to provide benefits to all actors involved in that process, such as increased scale and scope of activities through the combination of different technological competences, the sharing of costs and risk and an improved ability to deal with complexity.

Dodgeson (1994) has distinguished between vertical and horizontal collaboration. Vertical collaboration occurs throughout the production chain -and parallel to that, in the idea-innovation chain (Hage and Hollingsworth, 1999)- from the provision of raw materials and bold ideas through product development, manufacturing to marketing, distribution and services. Horizontal collaboration occurs between partners at the same level in the process.

Collaboration and cooperation between economic actors can take many forms. A specific kind of cooperation for instance, is the holding company or a conglomerate of firms. These two forms of cooperation basically have a bureaucratic administrative control structure that largely resembles the large vertically integrated firms. Hollingsworth and Boyer (1998) have listed the various kinds of coordination and governance principle in a matrix.

On the horizontal axis there is the organisation structure, ranging from the lack of a formal organizational structure, which is typical for market relations, to the bureaucratic administrative control structure of the hierarchy. The latter type of coordination is especially to be found in large, vertically integrated enterprises. On the vertical axis there is the motive of the economical actors, ranging from actors, purely motivated by self-interest, to actors who are informed, but also constrained by (social and ethical) obligations. The graph below has depicted the main positions of the various modes of coordination and governance.

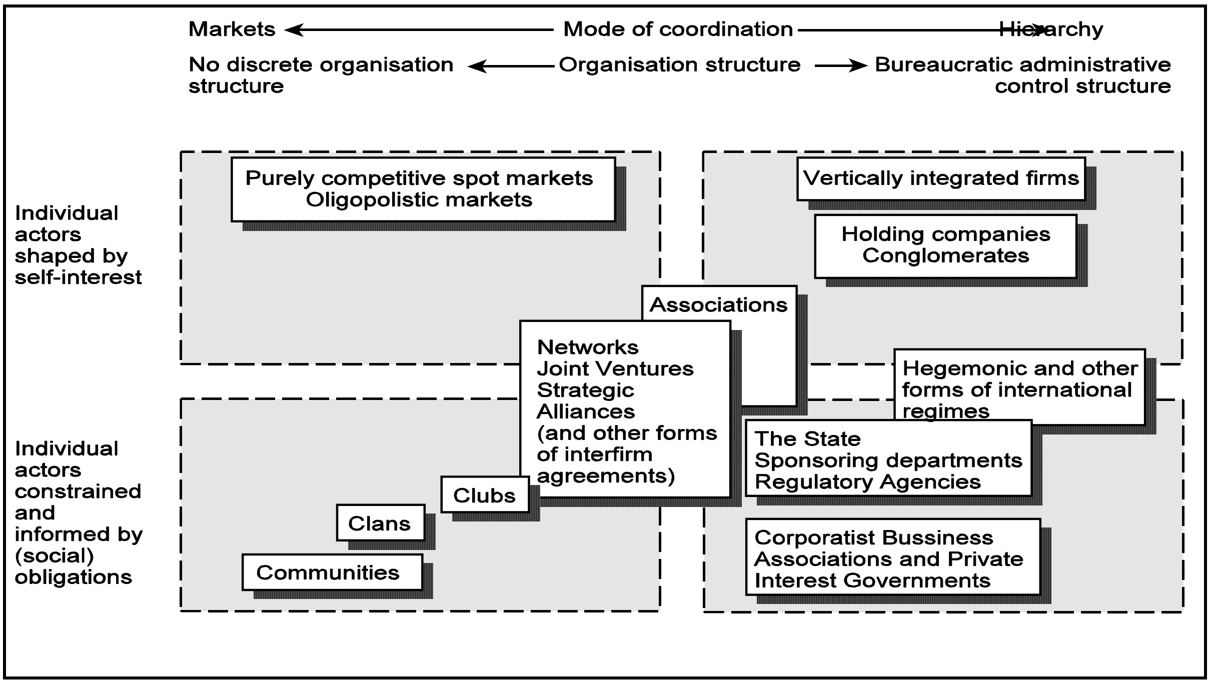


Figure 10 *Modes of coordination and governance based on Hollingsworth and Boyer, 1998*

Networks distinguish themselves from vertically integrated firms in that they do not have a hierarchic decision- and responsibility structure. They distinguish themselves from markets in that the actors in a network have mutually accepted a basic set of rules that govern behaviour. The actors in the network have found a balance between self interest and a commonly shared set of social and ethical principles. Associations, joint ventures, strategic alliances are all particular types of networks, each bending over to a specific set of rules and governing principles, as is depicted in the graph. Networks are thus to be seen, not only as standing between markets and hierarchies, but also as standing between organisation-forms which are rather based on self interest, and organisation forms which are based on (and constrained by) social obligations (cf. Hollingsworth and Boyer, 1998). Networks have been the mechanisms for coordinating prices, wages and purchases for some time. The most common examples were agricultural cooperatives, associations and cartels. Now many small firms can survive in specialised niches, but they frequently join in joint ventures with large companies that produce and/or market their products (Powell and Brantley, 1992). Even more complex alliances involving large numbers of organisations are being formed to accomplish tasks and objectives that no single firm could achieve on its own, such as establishing industrial standards, developing complex products as automobiles, semiconductors and aircraft, and expand the pool of industrial knowledge (Alter & Hage, 1993, Hage & Alter, 1997). The participants in networks share a commonly held belief in the goals of the network, even though they can fight about goals and membership, and they know that the only way to achieve the goal is through the behaviour of its participants. Networks assume a collective will, and collective effort of its members (Stone, 1997).

The importance of networks is growing especially in sectors which have to face rapid growth of technology. Metcalfe (1995) has suggested a definition that networks are to be seen as economic clubs acting to internalise the problems of effective knowledge transmission and Kogut (1998) has regarded network capability as a source of value to firms, contributing to learning and knowledge generation. Johannison (1987) characterised networks by the concept of ‘loose coupling’, in which various actors have developed relatively loose relationships, linking them in the pursuit of common goals. Grandori and Soda

(1995) have defined an inter-firm network as the mode of regulating interdependence between firms. Hage and Alter (1997) have added to this definition that networks cannot be dominated by a single organisation that has absolute hierarchical power, it rather must be governed by the collective will of its participants, and it operates through joint decision making, problem solving, and sharing of profits and prestige. It is especially the characteristic of sharing that distinguish networks from organisations. The standard assumption in organizational literature is that organisations strive to maintain their autonomy at any cost (Hage and Alter, 1997; Gouldner, 1959). Oosterwijk (1995) has summarised the major five major characteristics of networks. He found that:

- A network consists of a number of actors, each with its own interest and responsibility;
- The actors of a network are mutually dependent;
- The actors in a network are (whether actively of passively) involved in a certain issue;
- The relations between actors are not hierarchical
- A network is a specific, identifiable whole.

The establishment of network-relations and co-operation usually takes a relatively long period of time to develop. The willingness to engage in networking is not a given thing. The actors have to get acquainted to each other and it takes a while before mutual understanding and trust is achieved and the network can start its activity. However, once established, co-operative networks tend to be characterised by a high degree of specialization and interdependence, intensive communication, reciprocity and high levels of trust (Hämäläinen, 1993; Nahapiet and Ghoshal, 1998). But given the tension in networks between competition and co-operation, conflict is part and parcel of network relations. The exchange of knowledge is crucial in network innovation processes. Networks may have the capacity to combine the knowledge of the actors in new combination, but it is not a given thing that this will happen. Hämäläinen and Schienstock have identified four organizational factors which influence the innovativeness of networks: (1) diversity of knowledge, (2) intensity of communication, (3) availability of complementary goods, and (4) social capital.

Combining knowledge in novel combinations requires interaction and exchange between knowledge-holders and today, individual knowledge sets tend to be so specialised that the required diversity of knowledge for major innovations can only be reached, when two or more experts combine their different knowledge sets and create a new, partially shared knowledge base (Hämäläinen and Schienstock, 2001, p. 23). This requires that actors have access to each other, through a common cognitive framework, shared language, membership of the same community, overlapping knowledge structures, and a meta-level recognition of each other's knowledge domains (Nahapiet and Ghoshal, 1998; Hage and Hollingsworth, 2000).

Frequent and dynamic interaction of an organisation's tacit and codified knowledge lay the groundwork for the development of new knowledge. Informal relations in face-to-face communications help to establish the cognitive and social frameworks wherein different cognitive frameworks are combined into new mind-sets, leading to new insights and discoveries (cf. Bierly and Hämäläinen, 1995; Nonaka and Takeuchi, 1995; Daft and Lengel, 1986). The recognition of mutual dependency and the potential for synergy provides a network with an identity of its own, which allows participants to engage in networking on a base of trust, shared visions, reciprocity and mutual adjustment.

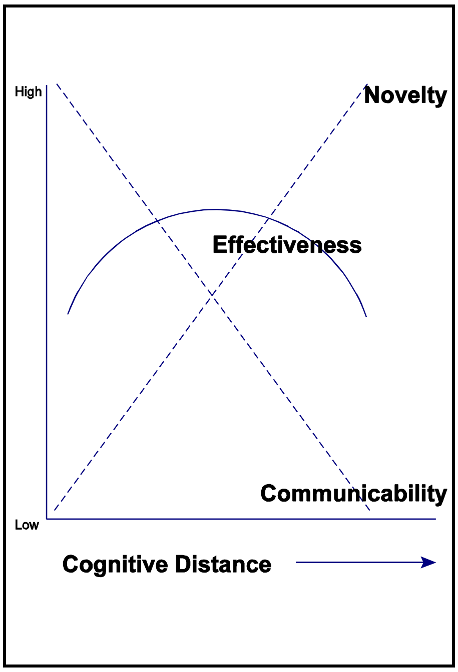


Figure 11 *Cognitive Distance according to Granovetter 1982*

Constituting an innovative network is a matter of careful balancing between differences and similarities. An innovative network requires a certain level of variety among the participants, because diversity of knowledge encourages learning and the generation of knowledge for the innovation process. But it is difficult to precisely distinguish the optimal balance between differences and similarities. Too much similarity among the participant does not generate novelty, but too many differences discourage the creation of a mutual framework of language, codes and understanding, which is a precondition for innovative effectiveness.

Building on Granovetter's work on the 'strength of weak ties' (1982), Nooteboom has argued that partners in a networks should -on the one hand- have sufficient 'cognitive distance' to each other. The actors in a network must possess different cognitive categories to be able to generate and capture knowledge that one could not have generated or captured by him-/herself. On the other hand, the partners must be sufficiently close in cognition and language to enable communication in a meaningful way. If the understanding of the other partners is complicated by a lack of experience, communication will be hampered. Strong ties may be needed when knowledge is tacit, based on enduring and intensive interaction, or when innovation needs to be in tune with other activities. Yet, strong ties may have the disadvantage of generating too little novelty and too much personal interaction, which may be an obstacle for criticism and flexibility.

A well-balanced approach is a mixture of a certain level of communication and a certain degree of diversity of knowledge; both not too little and not too much (Nooteboom, 1999; Hollingsworth (2000); Granovetter, 1982).

2.4.6 Innovativeness and firm size

An issue highly relevant, but not discussed so far, is the influence of firm-size on an actor's innovative performance. A debate over the innovativeness of large and small firms in industrial innovation has raged for many years. Some have argued that the large vertical integrated firm has the best capabilities for monopoly power, while other have argued that the small firms hold the best cards for innovative performance. 'Small is beautiful' in their view, because the small firm has little bureaucracy, rapid and effective internal communication, and a high degree of functional integration. Small firms sometimes have the advantage that regulations are not so stringently enforced and, on the whole, many schemes have been established to assist small firms in innovation. Yet, the most appealing feature of small firms is their flexibility and capacity to learn fast. Small firms, it seems, have a well-developed capacity to adjust to new routines and strategies. Especially small startup companies do not have to 'unlearn' entrenched habits and routines. Thus, on first sight it seems that the small firm holds all the trump-cards in the innovation game and large companies have to follow suit. This is understandable, because many managers in large firms seem to have turned into bureaucrats, lack the dynamism and enthusiasm for novelty, and expose risk-adverse behaviour. Internal communication in large companies is often cumbersome and technical manpower is often detached from other corporate functions. Furthermore, shareholders put severe pressure on management to focus on short-term profits. But the worst it seems, is that large firms are slow in learning, because they are locked in to well-established practices and routines.

However, comparing the advantages of the small firm with the disadvantages of large firms is not a fair comparison. Examples of inflexibility and bureaucracy of large firms do attract much attention, but easily distract from the fact that only a percentage of small firms have the capacity to be viable in the long run. The inclination to small firms as the most important source of innovation is a 'David and Goliath-game'. The image of the 'heroic entrepreneur' of a small firm who manages to turn an invention into a commercial success is appealing, especially when s/he succeeds where the large firm fails, but this is certainly not the rule. Even small firms that have been successful as a startup, often 'disappear' in mergers or lack the capacity for sustained innovativeness. Often, the managerial skills of entrepreneurs are limited and many small firms lack the time and resources to forge effective external science and technology networks. Small firms have limited capacity to spread risk or to get access to external capital for innovation. Its capacity to tap into the right resources is only limited as well as the awareness of what is going on outside in the firm's business environment. Opposed to these disadvantages of small firms we find the professional managers in large companies trained to handle complex processes, a high skilled staff in well-equipped R&D laboratories, easy access to science and technology networks, easy access to external funding, and a high potential to organise synergies across divisions.

2.4.7 Size and sector specific patterns

The debate on the innovative strength of small and large firms will remain unsolved as long as scientists do not have a good set of comprehensive databases to compare performance between different firm sizes. Rothwell and Dodgson have studied this issue and concluded that the contribution of small firms in innovation varies considerably across sectors of industry. The share of innovativeness of small firms in sectors like aerospace, motor vehicles, dyes, pharmaceuticals and shipbuilding has only been small, whereas the share in sectors like scientific instruments and specialist machinery is considerably higher. A rule of thumb is that where capital and/or R&D requirements and other entry costs are high, the importance of small firms in innovativeness is relatively low, and vice versa (Rothwell and Dodgson, 1994, pp.310-23).

The importance of small firms is especially to be expected in niche-opportunities which appear in the dynamic markets of highly innovative sectors where the use of knowledge and skilled labour is crucial. This is especially the case in New Technology Based Sectors (NTBS), such as for instance in modern biotechnology and semiconductors.

Dodgson has found interesting differences between semiconductors and related industries, and the biotech sector. Both technologies belong to the category of science-based technologies, but both technologies have distinctly different paths of development.

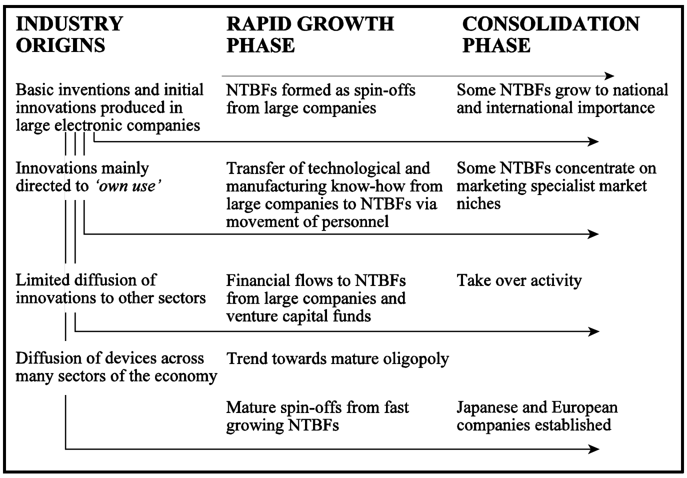


Figure 12 *The evolution of the US semiconductor and CAD industries*
(NTBF - new technology-based firms)
Source Dodgson, 1991

In the case of semiconductors, transistors, digital switching technology and adjacent technologies the initial inventions and innovative activity were to be found in the R&D labs of the large companies. Many of the inventions were initially made to suit the need of the company. They were originally simply intended for the firms 'own use', to establish a monopoly, which might give the company a technological head-start in competition with its main competitors. The small firms only came in sight in the diffusion phase, and many small firms started as spin-offs from these large companies. In this case the small firms 'followed' the innovations made by large companies as is demonstrated in the table opposite. Some small startups have emerged as the spin-offs from basic research, and some have even managed to gain national or international importance. Others start as spin offs, develop independently in specific market niches and still others develop independently, but were later absorbed by the large, vertical integrated firms. However, most of the spin-offs emerge when the products which were built on the initial innovation get widely diffused. Thus, the 'engine' of innovativeness in the semiconductor and related industries lies in the large electronics companies.

In modern biotechnology the source of invention and innovation has not so much started in industry. It rather has started at the universities and research institutes. The first startups have spun-off from these knowledge institutes. The bulk of inventive/innovative activity came about in NTBFs, while the commercialisation of new products, in particular pharmaceuticals is depending on the effort of the established large companies as is demonstrated in the table opposite. Here the small firms are the frontrunners in research and development.

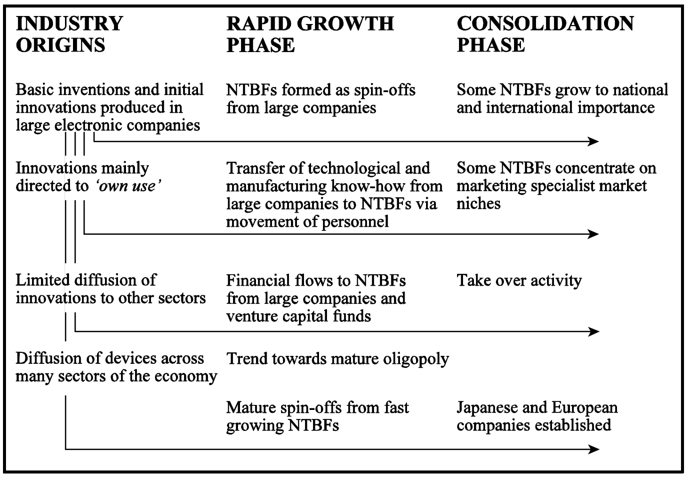


Figure 13 *The evolution of the US semiconductor and CAD industries*
(NTBF - new technology-based firms)
Source: Dodgson, 1991

In the innovation process many dynamic complementarities can exist between large and small firms. Small firms provide crucial elements to the innovation process of large firms and vice versa. The main distinctions regarding the advantages of firms size is that small firms especially benefit from behavioural advantages, while large firms gain from material advantages. However, it is important to emphasise that small and large firms do not operate in isolation; they are highly complementary in the innovation process (cf. Rothwell and Dodgson, 1994; Dodgson, 1991).

The differences in the innovative trajectories of the semiconductor sector and the biotech sector are highly relevant for our research. They indicate that within a given national system of innovation sectoral differences can exist between sectors, even if both sectors can be characterised as science-based technologies. The key to inventions and new technologies in both sectors are hidden in different places along the idea-innovation chain and the role of large and small firms differ considerably between sectors.

The question is if these different trajectories and roles will be persistent over time? One scenario is that they will converge over time, due to maturity of the sectors. Modern biotechnology in that scenario is a relatively new sector and only the initial innovations are sparked by the knowledge institutes. However, as companies develop their own skills and have the funds to do so, they will be able to generate new knowledge. In this scenario it is just a matter of time before the trajectory and roles resemble those of the semiconductor-industries. An alternative scenario is that the differences will be persistent. The developments in modern biotechnology are so dynamic and diverse that it is prohibitive to firms to take the lead in this type of research. They rather scout what is going on in the most important laboratories and absorb promising firms through mergers and take-overs.

2.5 The institutional dimension

2.5.1 Institutions

The literature on 'national systems of innovation' has argued that the innovative capacity and performance of a country depend on its institutional structure (Dosi et al. 1988; Lundvall, 1992; 1998; Nelson, 1993; Edquist, 1997; Freeman and Soete, 1997). However, much of the analysis has focussed on institutions as being a specific kind of organisation. In that line of reasoning, the institutional research funding-system has often been reduced to banks, venture-capital funds, the stock market as discrete organisations, thus largely neglecting the underlying values and norms, that have provided the system with its general blue print for communication and interaction. Rather than discrete organisations, institutions are to be seen as sets of habits, routines, rules, norms and laws, which regulate the relations between people and shape human interaction (Johnson, 1992). Institutions help to structure both information and behaviour in a system of innovation and thereby retain and transmit characteristics and information. On the one hand they provide stability in the patterns of social interaction, thereby reducing uncertainty for individual decision makers. On the other hand institutions are flexible and will be re-created through continuing and social interactions (McKelvey, 1997, p. 206) They will change, more or less in tune with changes in technology (Freeman, 1987; Perez, 1983)

Institutions are the formal and informal rules, norms, habits and convictions that regulated human behaviour. They serve as signal-posts for social and economic behaviour and they have crystallised in encompassing social systems, such as the regulation system, the financial system, the education and training system, but also in the ways how actors 'trade' labour on the labour market. Institutions have a enduring character. Societal actors learn in a process of socialisation how to cope with problems, how to solve conflict, how to threat and trust other humans. It is an enduring system because actors have accepted and internalised the concepts for proper societal behaviour as their own. Each time they use these concepts, they reinforce the relevance of these concepts and strengthen the institutional structure. Thus, societal behaviour is not only the product of the institutional structure, it is also the process that gives institutions stability over time. It follows that the institutional environment in our analytic framework reflects enduring sets of mutual expectations, crystallised in rule systems. Rules -both formal and informal- define what is to be expected of social actors in a specific role and a specific social situation (cf. Van Waarden, 2001, p. 770).

Now we can broaden our notion of institutions beyond the most obvious definition as the system of rules, norms, habits and convictions. In fact we will refer to institutions as a layered and intertwined system.

The backbone of institutions is in the system of informal rules, regulations, habits and convictions, that guides the actor's behaviour in social and economic life. This informal rules-system has partly crystallised in formal rules of conduct. Laws, rules, agreements, contracts and the like, give instructions regarding how societal subjects should behave as proper citizens. They demarcate the public space from the private space, delineate what is right and wrong, or who is entitled to something and who is excluded. Laws and rules thus help to structure social life. Citizens accept that the state has a say in education, but expect in return that the state will also create the right conditions for a proper education. We accept that the state has exclusive right to use force, but expect in return that the state will defend the country against foreign intruders and takes care of safety in the streets. Thus, formal rules regulate societal behaviour, and they also provide the resources to institutional sub-systems. The education-law for instance, carefully outlines as from what age a child should attend school, but it also provides the resources so that a child can be educated. It regulates the conditions under which a school can be founded, that teachers should have the proper level of qualification, but the law also provides the funds to hire such teachers.

Much in social life is covered by formal rules, but not everything. Informal rules remain important, because they give meaning to rather abstract concepts such as community, solidarity, a sense of belonging, dignity, respect, self-esteem, honour, love and friendship. The concept of decency is generally well understood by citizens, even though formal rules do not apply. Thus, the concept of decency is an informal concept, known to everybody, but not strictly codified in rules.

The system of formal and informal rules is country-specific in nature. Even neighbouring countries hold different views. Take for instance the matter who is qualified for a professorship. Even though it is not written down in rules, in Germany it is customary practice that only candidates who have passed the Habilitation can apply for a professorship. The Germans are also very reserved towards a sponsored professorship, while the Dutch have a much more lenient attitude in these matters. The Dutch accept that large companies or societal organisations have a say in the appointment of professors, while the Germans regard the appointment of professors as a strictly academic matter. The task to review candidates is the informal prerogative of his/her future-peers. Thus, social norms, often unwritten, regulate social behaviour in a country-specific way.

The institutional sub-systems which perform specialised tasks, such as finance or the generation and transfer of knowledge have evolved into discrete organisations. In the financial system we find banks, the stock-market and venture-capital funds. In the knowledge system we find schools, vocational training-centres, universities and graduate schools. Some of these institutes are not only active in the dissemination of knowledge, but also in the generation of knowledge, especially universities and graduate schools. Here we also find entrepreneurial firms in science-based industries, and (public and private) research institutes.

Institutions have thus materialised in institutes, as discrete organizational entities that formulate and implement rules, formal as well as informal. Government, Ministries, public agencies and inspection services formulate, reinforce, implement and supervise the regulatory system. All these institutes tend to develop their own dynamism to sustain and reinforce their own existence. They lobby for the maintenance of their interests and resources, and for sustained development.

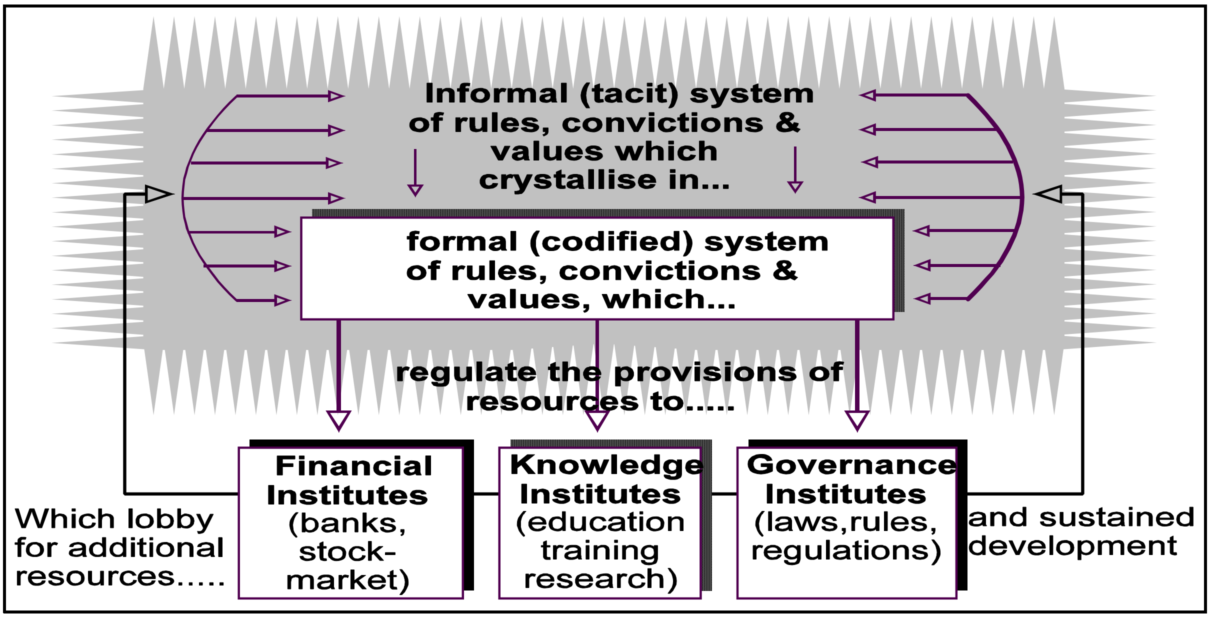


Figure 14 *Various aspects of the institutional dimension*

Now we can identify five interrelated functions of institutions, as is depicted in the graph above. Institutions refer to:

1 The body of informal rules, habits, norms and convictions (which has crystallised in);
2 The body of formal rules (which);
3 Regulate the provision of resources (to);
4 Discrete institutes (which);
5 Lobby for additional resources and sustained development

In our analytical framework we are particularly interested in how these institutes function as discrete organisations. For instance, how vocational training centres, universities, graduate schools and research institute have organised innovative activities within their own organisation or how they cooperate in research projects with other knowledge institutes and industry. However, if we just would concentrate on the structure of the (inter-) organizational relations, we would not grasp the full picture. It is important to understand the institutional environment in which these organizational arrangements have been established.

2.5.2 The problematic difference between institutions and organisations

Our concept of institutions may be confusing. In our analytic framework we have distinguished between the organizational and institutional dimension, but it is difficult to delineate whether the functioning of an actor should be contributed to the organizational or institutional environment. From what we have stated in the introduction follows that institutions help to reduce uncertainty among social and economic actors. Institutions provide the general concepts for social and economic behaviour, a general set of rules to manage cooperation, to provide information, to help overcome conflict, and to provide incentives for the innovation process. This is highly relevant because innovation is an activity surrounded with risk and uncertainty and a substantial part of innovations is to (learn to) cope with uncertainty. Rules, norms, conventions and general patterns of social conduct provide information about behaviour and search directions. More important: they help to shape the balance between behaviour building upon opportunism and lack of mutual trust, or upon honesty and trust (Lundvall, 1992 a, p. 61). This is especially relevant for innovative activities, because firms rarely innovate in isolation. Usually they are entangled in various forms of cooperation with other economic actors, trying to bend more or less rigid organisation forms towards more flexible forms. In this process, management has to trust and rely on qualifications, integrity and honesty of the employees which have a delegated responsibility to participate in networks, and who have to find a balance between self-interest and the joint efforts of the network. Increasingly we find the innovative firm interacting with actors in, more or less flexible social environments, such as other companies, knowledge institutes, political actors, administrative bodies, regulative bodies and other agents. This is a social process, on the one hand guided by the institutional context of cultural habits, but on the other by laws, rules, regulations, education systems, financial systems, labour-market systems which shape and influence innovative behaviour. In this sense institutions are conceptualised as to pattern behaviour, e.g. routines, norms, shared expectations, morals, including the set of ground-rules for economic behaviour, such as property rights, contracting, etc.

Yet, we can also think of institutions in accordance with the everyday meaning of the term. This way is not so much based on theories, but builds upon empirical observations, in which institutions appear as concrete social entities that deal with specific tasks. The institutional setup of the healthcare system for instance, provides the basic outlines of how to deal with matters of health and related issues, but the hospitals are the concrete organizational entities. In a similar mode we can identify several institutes where innovative activities take place, such as technical universities, industrial research institutes, R&D departments, patent offices, technological service institutes and other bridging organisations.

This is easily confusing, because there is no clear distinction between organisations and institutions. Often these terms are used as synonyms in everyday life; a university for instance is an institutional concept, but also a concrete organisation. It is an institute, because it has evolved from the institutional setup: 'the system for higher education'. This system is an institutional concept in that it shares a particular set of expectations, norms and rules regarding higher education. The institutional system defines who can enter the system and on what conditions, what is funded and what not. It has general norms and rules about classifications, holds general ideas about the 'value' of a diploma and the academic skills that one has to master. All the universities belong to that very same system and share its norms and rules. But each university is also an institute and thus, a discrete organisation, with its own rules, management style, division of labour and mission statements.

In the context of this study we follow Edquist and Johnson who have argued that organisations are formal structures with an explicit purpose and they are consciously created. They are the players and actors. In contrast, institutions may have developed spontaneously and are not characterised by a specific purpose (cf. Edquist and Johnson, 1997, p. 47).

Institutions, thus refer to the distinction between the principles and processes that regulate economic behaviour on the one hand and organisations that operate within this framework of rules, on the other (Smith, 1997, p. 87). Mostly, they have evolved over time as relative isolated subsystems in a society in response to a variety of demands in the past and they are the outcomes of path dependency, state formation and industrialisation (Van Waarden, 1998, p. 19). Institutions exist because they serve, or have served some specific functions. Empty institutions seldom survive in the long run (Polanyi, 1957).

Institutions have the capacity to reduce uncertainty, coordinate the use of knowledge, mediate conflict and provide incentive systems (Johnson, 1992, p. 26). In general we can say that institutions serve as signposts for the processing of information. Information is channelled, filtered, attenuated or amplified by the system of norms, habits and routines. They help to reduce the amount of information needed for decision-making. They make it easier to be rational in a complicated world. This is especially true for the ability to channel conflict within organisations, for setting out a pattern for co-operation, and for the management of conflict. Institutions provide the sticks, sermons and carrots[4] of economic life. They provide the authority to enforce behaviour, the convictions to persuade an actor to a desired kind of behaviour and the economical incentives for desired behaviour.

Property-rights on knowledge and ideas for instance, provide a clear incentive to innovate. Patents provide a temporary monopoly on the commercialisation of a particular idea. However, the softer side of institutions also provides incentives, especially when entrepreneurial spirit is highly valued in society. 'Belonging to a winning team' for instance, can be an important motive to engage in innovative activities. If an economy is not able to generate the desired amount of innovativeness, a special programme can be designed to stimulate innovativeness and channel resources into the innovation process. These programmes are usually meant to initiate activities or fuel the first sparks of innovativeness. Thus, in general one can say that institutions have an important role in the stimulation of innovativeness. They shape the context in which innovative activities are fostered, stimulated or hampered.

Yet, there is also a dark side on institutions. Institutions provide stability to the economy, but there is only a thin line between stability and rigidity. Institutions sometimes have the tendency to become a target in themselves. The ability to adjust to societal changes is an important precondition to provide the functions described above (cf. Edquist and Johnson, 1997).

2.5.3 Relevant institutional arenas for innovation

Johnson has treated institutions as informational devices that govern perceptions and put them at the heart of all learning processes. Social interactions help individuals to form a conceptual basis necessary to understand, learn and act in a complex society (Johnson, 1992, p. 27). Douglas has stated: "Institutions think. We recognise, classify, remember and forget in accordance with institutions. Particular ideas and ideals dominate in particular institutional and cultural configurations. An 'instituted community', which could be a firm or a network of firms, has a profound influence on the learning going on within it." (Douglas, 1987)

In the present situation, in which technological possibilities are in flux, and in which technological trajectories are not firmly established yet, openness and diversity of learning processes are of central importance for the innovation process (Perez, 1985). A flexible institutional environment might bring the skills, experience and knowledge of different people, organisations and government agencies together, and get them to interact in new ways, stimulating innovation processes (Johnson, 1992). Learning by doing, learning by using, learning by searching and exploring, and even learning by disaster, are of crucial importance for the innovative performance of sectors and countries.

Institutions, most relevant for the innovation process concern the functioning of the knowledge, education and training system; the financial system and the regulation system, because these systems provide the resources for the innovation process as well as they put constraints on what can be researched and not. Institutions delineate the 'play-ground' for research and innovation.

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[4] The stick, sermon and carrot are the proud nicknames for specific sets of policy tools. The *stick* refers to the legal instruments, which can be used to force subjects to obey to the rules. The *sermon* refers to the communicative instruments which are used to convince subjects or to re-frame a problem. The *carrot* refers to economic instruments, which regulate behaviour through economical incentives (subsidies) or economic sanctions (levy tax).

The knowledge system

Organisations and institutes that provide knowledge, skills, training and education, are a vital component of long-term economic development. Such institutes and organisations can create human resources in the form of well-trained technicians and scientists, who are able to generate new forms of knowledge. But whereas these assets are mainly used to fuel the process of generating new knowledge, these institutes can also provide knowledge in a more direct sense, in the form of scientific papers, conferences, prototypes, demonstrators, new materials, new components, and the like. In this context we can think of the system of higher education with its centres for vocational training, universities, graduate schools, research laboratories, and technology transfer points. We also think of intermediary institutions who disseminate knowledge and bridge the distance between science and industry.

However, not only the existence of these institutes is important, but also the way how they are connected to the organizational elements of the idea-innovation chain. Take Finland as an example: the close interactions between Finnish academia and industry, and a general openness towards new technologies, have supported the development of a most competitive telecommunication sector, which has given Finland its competitive economic advantage (Schienstock and Tulkki, 2001, p.38). Furthermore, Finland has formulated a set of high-pitched starting points for its science and technology policy. One such starting point is that personnel in R&D should always equal (or exceed) one percent of the national workforce and this is backed-up by high expenditure on R&D (NRC/Handelsblad, 2002)

In the same line of reasoning, Freeman (1992) has argued that the loss of British technological leadership at the end of the nineteenth century was not so much caused by the fact that Britain ceased to make scientific discoveries or radical innovations. It was because the British institutions were incapable of diffusing the innovations, scaling them up and use them in a wide variety of new applications. In line with this argument, it was the institutional innovations in a narrower sense that enabled the German and American industry to exploit scientific knowledge more effectively. Germany was the first country to develop the network of formal professional research and technical organisations and the 'output' of this system was a wide availability of well-trained engineers for industrial R&D laboratories. This institutional advantage gave the German system a head-start over other countries in industrial innovation.

Thus, the relation between knowledge-producing organisations and institutes and knowledge-consuming organisations is important for the understanding of innovativeness. Can knowledge gently flow and find its bedding, or is the flow characterised by the obstruction of many rapids? How do firms acquire knowledge and how are they connected to science?

The training system and labour mobility

Dissemination of knowledge and acquiring working skills is as crucial for the innovative performance as the generation of knowledge. Basic to all innovation analysis is the idea that innovation and the development of new technologies occur through the activities of skilled personnel: researchers, engineers and managers. Innovation is a social process, involving not only techniques (such as new items of equipment) but also new forms of knowledge, skills and competences. Competence is embodied in the collective experience and activities of people who produce and implement a new technology; it relates not only to research results, but also to matters of organisation, problem solving, marketing and so on (Smith, 2001). One can acquire technological skills at vocational centres and universities, but the knowledge how to use these skills in daily practice can only be acquired in a working environment. Furthermore, knowledge and skills acquired in formal education programmes have a generic character, and are not always sufficiently geared to meet the requirements of business and industry. That is why training-centres and systems of apprenticeships are especially important. They serve as a practical training-ground where generic knowledge is cut to size.

An apprenticeship is often used as an integrated part of formal education, but especially in high-tech environments, the first years are often used as an extended education and training programme. Firms have accepted that employees can only be productive if they have acquired the skills and knowledge to perform high-pitched research tasks, and several firms actively create conditions for researchers to do PhD research. A position in research departments also provides an excellent training ground to learn the breadth of a firm and to prepare for future management positions.

David Jeremy has pointed to several historical cases in which America managed to acquire British machinery in the early 1780s, but was unable to operate it. A complete spinning machine was acquired in 1783, but after four years, no-one had been able to erect it, let alone operate it (David Jeremy, cited in Smith, 2001). From these historical cases it follows that experienced workers hold valuable assets. That is especially the case in high-tech industries. Workers not only hold generic knowledge, but also specialised knowledge acquired in a particular working environment, which allows them to perform highly specialised tasks. Labour mobility is an important asset to the national system of innovation. A system of easy 'hire and fire', such as in the USA generates a different kind of dynamism than a system of long-term contracts, such as in Germany.

The financial system

'Innovation ... involves uncertainty, risk taking, probing and re-probing, experimenting and testing. It is an activity in which 'dry holes' and 'blind alleys' are the rule, not the exception.' (Jorde and Teece, 1990, p. 76). Van Waarden has argued that innovation is more often characterised by uncertainty than by risk, because technological development is full of unforeseeable contingencies. For risk the probability of risk can be calculated, but for uncertainty this is impossible (van Waarden, 2001, p. 768). If, then, innovation is so unpredictable on the one hand, but also so important for a country's economic development and the other, the matter of financing innovative activities is most relevant. How do financial institutions like banks, investors, venture capital funds and business angels perceive risk and under what condition are they willing to invest in such risky undertakings?

Steven Casper has provided us with an excellent example of his case study on risk-seeking behaviour in US and German biotech firms. He found that the orientation of biotech startup companies differed considerably between the US and Germany. The US has a 'high-risk orientation'. Pharmaceutical companies are searching for new vaccines to fight diseases like Alzheimer, AIDS, cancer, asthma and the like. It has been estimated that only one out of every 10.000 new drugs synthesised in the laboratory, ever leads to a marketable product (Committee on Contraceptive Development, 1990). Germany rather has a 'low-risk orientation. Startup companies are much more involved in platform technologies, which have rather broad applications, and which can be used in several fields. The explanation of the differences is to be found in the analysis of three important competencies for innovative startup firms:

– High-powered incentive structures for employees;
– High-risk financing;
– Viable career-structures for employees of firms that run the risk of failure.

Research in the US biotech is usually funded by business angels and venture capital funds. The step from venture capital to the stock market is relatively easy in a market-based financial system. In German biotech research funding structure, there are government agencies and banks that fund the initial phase of the startup. The US system of funding is basically a one-way system of communication to convince lenders about the merits of the project. It, furthermore, has a rather short-term orientation governed by the psychological determined peculiarities of the stock-market. The German system is rather to be characterised as a coordinated market-economy (Soskice, 1994), embedded in networks of powerful trade and industry associations. Historically, the provision of money used to take place in a credit-based institutional environment, involving two-sided communication with a tradition of risk sharing (Casper, 1999)[5]. Firms' relationship with banks is accordingly close, and lending is relational, that is each loan is seen as part of a long-term relationship in which the firm is bound to inform the bank fully as to its position and prospects, and the bank is committed to support the firm through bad times, in return for influence over its policy and personnel (Tylecote, 1994, pp. 262-3).

The regulatory system

Institutions as enduring sets of rules of social expectations, have most clearly crystallised in the regulatory system. Laws, rules and regulation have clearly delineated what is allowed and forbidden and it is often thought that the more encompassing the system of regulation, the smaller the room for development. However, that is not always the case. In a public sensitive sector as biotechnology for instance, an extensive system of rules and regulations have been formulated. These rules not only regulate and protect ethical behaviour and good laboratory conduct, they also define an extensive set of rules to protect the environment and the interests of employees, they regulate transport of possibly hazardous substances, they regulate medical-scientific research conduct, etc. An extensive system of licencing has developed in recent years and several agencies and advisory committees have been established. This system of regulation puts severe constraints on what is allowed to research and what is prohibited. In this sense regulations indeed put constraints on innovations. But rules and regulations also help to reduce risk and uncertainty to manageable proportions, by decreasing the unpredictability of mutual social expectations and the arbitrariness of social behaviour (van Waarden, 2001, p. 770).

Many social rules have crystallised in discrete institutions. Intellectual property-rights for instance, which grant a temporarily monopoly to the inventor, are controlled by patent offices. The land registry office regulates the rules regarding the possession and the exchange of lands and real estate. Both offices are to be seen as the executive branches of these particular sets of rules. Technological fields, especially those technologies which have a reach beyond national borders, have their own sets of rules to lay down the standards for large technological systems, with the standardisation offices as the executive offices.

Thus, on the one hand rules and regulations put constraints on innovative behaviour, but on the other hand, they help to reduces uncertainty, which supports the attractiveness of innovations.

2.6 The meta-institutional dimension

We have conceptualised institutions as sets of habits, routines, rules, norms and laws, which regulate the relations between people and shape human interaction, which set out the framework for mutual expectations. Many of the institutions have crystallised in discrete organisations or institutes, which are entrusted with the authority to perform specific tasks, such as enforcement and inspection; or to play a role in the generation or diffusion of knowledge, like schools and universities; or in the provision of

[5] Germany has often been used as the pre-eminent example of a credit based institutional system (Christensen, 1992) or bank based financial system (Tylecote, 1994). However, it should be noted that these characteristics are under change and there is a development moving in the direction of a more market-based capital market. The opening of the Frankfurter 'Neue Markt' and the increasing availability of venture capital has pushed the system away from its purely credit-based orientation.

capital, like banks, etc. What largely remains hidden are the underlying conventions of social behaviour. Most of the societal norms, routines and habits are internalised in someone's upbringing and education and have grown to a person as a part of someone's personality and it is rather difficult to bring these rules to the surface. This is especially true for general social values like trust, reliability, notions of relations, friendship and love. These general values are to be seen as meta-institutions, as they have a general meaning for all human conduct. Meta-institutions, or culture has provided us with the fundamentals of social live. These fundamental normative and ontological axioms are not to be found in a written set of 'rule of conduct'; they are rooted at the deepest levels of human personality and regulate opinions about the nature of man.

In general, cultural values have a sense of permanency. They do change over time, but there is a strong and dominant body of sustainable elements. Social values exist as memory-tracks, handed over from generation to generation. The implications are far-reaching and constitute national idiosyncrasies. Van Iterson (1997) has argued that the governance principles in the Netherlands, such as the principles of collegiality, joint decision making and the strong preference for compromise, can be traced back to the late medieval and early-modern Dutch social and economic development. Also Goudsblom has argued that with the foundation of the sovereign republic of seven provinces in 1648 national institutions were developed, and, among the elites, a national identity (Goudsblom, 1988, p.36). Joint decision making, the sharing of risk, team-work, a corporatist attitude and power-formation through coalitions have been part-and-parcel of the Dutch culture. This is reflected in the low power distance between managers and workers in Dutch enterprises. The management ethos is one of aversion against overt display of power or hierarchical differences (Lawrence, 1991) and in general, managers show a willingness to listen, to talk, to consult, to explain, to restrain from verbal violence and directives on authority (d'Iribane, 1989). However, the other side of the medal is that the final decisions are made in the board-room. The Dutch consensus management-style, is rather to be seen as a specific way to handle tensions, than it is a way to involve workers in decision making.

The consensus style of governance is still present today. The Dutch have developed a rather modest attitude toward the regulation of social and economic relations. They rather postpone decisions or await a better moment to compromise, than actively step into juridical conflict and litigation. There is a relatively high degree of trust and cooperation between state agencies and business firms (van Waarden, 2001, p. 773). The Netherlands clearly belongs to the group of consensual countries, which value consensus more than majority votes (Lijphart, 1984).

The meta institutional dimension encompasses the ethics, norms and values which are to be seen as the touchstones for proper behaviour. They also encompass tradition and historical ties, which have come to existence in a process of path dependency. The impact of culture does not influence our behaviour actively on a conscious level; we are usually not aware that our daily behaviour is modelled and constrained by tradition, but when confronted with other cultures we come to realise that we have certain preferences in common and recognise those preferences as group-specific. The strength of these systems is such that many conduct-systems tend to have also hereditary characteristics. They outline the normative precepts, such as the orientation on basic value properties and the identification with groups or other entities which are important for a particular group. They are to be seen as the fundamental positions concerning the basic strategies for achieving core values within the sub-system (cf. Sabatier, 1988; Sabatier and Jenkins-Smith, 1997). However, social and economic relations are not just ruled by families, professions or class; they are also ruled by nation specific characteristics. Our societal institutions are to be seen as crystallisation points of the cultural dimension. Our laws, rules and regulations reflect the values of what we think important as a nation. Our education-system is embedded in traditions, culture and history.

In each reform of the education system we can recognise the then dominant values in society. In a similar vein we use 'mental maps' which prescribe how to behave in society, how to solve problems, how to communicate and how to reach solutions. These mental maps are remarkable stabile. Even war, political turmoil or fluctuations in the economic situation, no matter how hopeless they may seem, do disturb the basic characteristics of the system.

Compromising and networking are key in a characterisation of the Dutch culture (Andeweg and Galen, 2000; Iterson, 1997). Dutch corporatism is in line with its traditional ideas of regulated markets, which explains Government's involvement in so many sectors of the economy. Yet, the style of governance is accommodating, pragmatic, with a high degree of trust and cooperation among economic actors and government, and a high degree of self organisation. This is supported by the historical presence of well-developed trade organisations, capable of such self organisation (van Waarden, 2001, pp.775-6). Dutch working relations lay stress on egalitarian group and power structures; they denounce abuse of power by top-level government or corporate leaders, and have a zest for communitarianism and community participation (cf. Hood, 1998, p. 26)

Culture is, thus, a powerful meta-institutional influence that usually remains hidden in common behaviour and common concepts of logic. It floats to the surface, especially through comparison with other cultures, which use slightly different sets of general conventions and a slightly different kind of logic. The basic notions of risk, success and failure for instance, differ considerably between countries. Bankruptcy in the Netherlands is usually associated with negative feelings of failure and quilt. Bankruptcy in the US on the other hand, has a much more positive connotation, because it is seen as inherent feature of entrepreneurship and risk-taking. Thus, culture defines the general values towards risk-taking and entrepreneurship. It also defines openness towards new ideas and technologies and defines an attitude in matters with an ethical component.

Organizational behaviour is thus embedded in meta-institutional and institutional behaviour. Organizational behaviour in this nested system, reflects the dominant norms and values of society. The ethical discussion in biotechnology, on the use of embryos for research-purposes, or the perspectives of several strains of therapy are for one part ruled by legal requirements, as they are to be found in (codified) laws, rules and regulations. For another part they are guided by general notions of decency, proper behaviour, which have become the backbone of a person's personality in a process of enculturation.

2.7 Different approaches in systems of innovation research

Our model of analysis starts from the premises that the innovative performance of a country depends on the complex interplay of activities of organizational actors in a complex (meta-) institutional environment. In the organizational dimension we focus on how economic actors have organised innovation activities. We discuss the division of labour between functional departments and/or companies, how these activities are governed and coordinated, and how cooperation within and between organisation takes place. In the organizational dimension the main focus is on how economic actors have organised innovative activities.

In the discussion of the institutional environment we take a different point of view. Here we focus on the characteristics of the systems of governance, the system of finance and research-funding, and the systems that have a role in the production, transfer and dissemination of knowledge. We are especially interested how these institutionalised systems influence innovative activity in the organizational dimension. Thus, in the organizational dimension we focus on how actors have organised innovative activities. In the institutional dimension we will try to find answers to the question why economic actors have organised their innovative activities in the particular way they did.

We will argue that the activities in the organizational dimension are a function of the institutional structure. That the preferences, habits, convictions, norms and values that actors hold, shape the framework for social and economic behaviour. Agents work together, because they believe that cooperation is (mutual) beneficial. They trust each other, because they value honesty and decency, and for that same reason they refrain from tricks and foul play. Managers grant responsibility and discretion to subordinates, because they trust that subordinates will use these in a responsible way. Organizational behaviour is thus rooted in institutionalised and internalised behaviour.

Yet, what is the most relevant institutional environment in systems of innovation research? On what level of aggregation should we analyse the institutional dimension? Is it a true national system of innovation or is it rather a regional system? Should we thus, follow the rapid expanding body of literature on national systems of innovation, or should we take another approach? Some have argued that the region is the best unit of analysis to study innovativeness and these authors found evidence in the eye-catching performance of several regions: Silicon Valley in the USA, Tuscany in Italy, Pirkanmaa in Finland, Baden-Württemberg in Germany, etc. These authors have tried to apply the concepts of the systems of innovation literature on regional developments. The remarkable performance of such regions challenges the question if we can design an innovative region as an encompassing master-plan from the drawing board, and thus create an innovative environment?

Several authors have argued that the characteristics of the innovation process are no longer national. In their view the influence of the nation-state has been forced to the background by processes of globalization and internationalisation. Technologies have their own characteristics which force innovation processes beyond the borders of the nation state. Especially modern ICT's have provided the tools that have helped to build and extend international and global innovation networks. Again others have concentrated on the historical characteristics of the innovation process and have argued that agents' behaviour is internalised through path-dependent processes and routines.

In this section we will explore the usefulness and fit of these different approaches. First we will address the relevance of geographic entities in the systems of innovation research, such as the nation and the region. Then we will discuss the approach that basically ignores the geographical entity as being the most relevant (institutional) environment. The technological system of innovation approach takes the dynamism that is inherent to certain 'grand technologies' as a starting point for innovation research. Having then, familiarised with the different approaches, we can subsequently elaborate on the question whether one can design an innovative environment as a 'grand design' from the drawing board.

Yet, the question which approach has the best in innovation research fit cannot solely be answered from contemporary research results. Today's innovative performance is strongly influenced by yesterday's events and experience, and in this context we will discuss the concept of path-dependence and bounded rationality. In this view the innovative performance is the result of historical peculiarities which ingrains the technological and institutional solutions that actors have developed in the past. We believe that this process of enculturation and internalisation is partly nation-specific, and partly sector-specific. Within the broad institutional outline of a country, we expect to find sector-specific variations that explain why the dynamism in one sector differs so much from another. Therefore, we will present our own approach and outline the concept of a national-sectoral system of innovations.

2.7.1 The role of the nation state in innovation research

Until now we have discussed institutions in a rather broad sense, as general sets of rules, habits, routines and convictions that regulate social and economic behaviour between actors. Yet, is this broad and general institutional framework strong enough to explain the innovative performance in each sector of the economy? Is the impact of the institutional setup felt the same in each sector? And, does the institutional setup provide the same possibilities and constraints to each and every sector of the economy?

Nelson has argued that the concept 'national innovation systems' is problematic for several reasons. First, one cannot draw a line neatly around those aspects of a nation's institutional structure that are concerned predominantly with innovation in a narrow sense excluding everything else, and still tell a coherent story about innovation in a broad sense. Second, the term suggests much more uniformity and connectedness within a nation than is the case. In his view one may discuss one sector pretty independent of another, and find important differences, and thus, innovation systems tend to be sectoral specific. However, if one broadens the focus, the factors that make for commonality within a country come into view, and these largely define the factors that make for commonality across sectors within a country. In a comparison of countries it will be hard to come away without the strong feeling that nationhood matters and that it has persuasive influence. In all cases, a distinctive national character pervades the firms, the educational system, the law, the politics and the government, all of which have been shaped by a shared historical experience and culture (Nelson, 1993, p. 518).

Yet, nations are difficult concept to grasp. What constitutes a nation, but also, what limits it? We only have to look at the recent past to see that seemingly stable structures have fallen apart. Regions have gained independence and countries have split up into smaller units. The driving force behind these processes is that people have shared beliefs about what binds them together and what is foreign to them. Anderson sees nations as imagined political communities - imagined as both inherently limited and sovereign. Renan defines a nation as 'a large-scale solidarity, constituted by the feeling of the sacrifices that one has made in the past and those that one is prepared to make in the future (Renan 1882/1990, and Anderson (1935, cited in Elam, 1997). Obviously, the nation is embedded in the whole of convictions, ethics, history and values that communities share, but still the borders are fuzzy. The strongest evidence for what constitutes a nation is in its rule system. The rule system largely reflects the ethics, values and history, that people share. The rule system distinguishes one nation from another and provides the frame of references for the building up of institutions, routines, customs and style. In this sense we follow Nelson's analysis, that national policies, histories and cultures are stamped into the economic and institutional actors in a county.

Yet, the question remains if the nation state is the best unit of analysis for innovation research, if the differences between technological sectors are considerable? We will return to that question when we present our own approach.

2.7.2 The role of regions in innovation research

In recent years, several authors have taken the spatial context in which innovative activities take place as a starting point for analysis. Whereas 'national' boundaries aim at identifying actors that share a common culture, history, language, social and political institutions (Lundvall, 1993), regional (or even local) boundaries refer to a specific region or area, characterised by well defined historical, social, cultural, or productive features (Breschi and Malerba, 1997). What triggered this new focus on the spatial dimension of innovation was the recognition that a great deal of innovative activity appeared to be taking place in the form of local or regional agglomerations, latter-day equivalents of the specialized industrial districts (Cooke and Morgan, 1994, p. 25). The most eye-catching example is Silicon Valley in California, which is known to be a benchmark for a true innovative, highly dynamic industrial environment. Its geographical counterpart, the Boston area along route 128, is often mentioned as an example of an area with a distinctly different character and a distinctly different institutional setup. Saxenian has devoted a comparative study on the culture and competitiveness of both areas (Saxenian, 1994). Castells and Hall (1993) have studied regional developments and used the generic name 'technopole' for regional activities, which have been the result of intended regional developments. However, they also used the name for various kinds of regional co-operations, building on public/private partnerships. Technopoles have the specific institutional setup of quasi-public and non-profit institutions, such as universities and research institutes, which are strongly involved in industrial developments.

Cooke has conceptualised a regional innovation system. The origin of the concept lies in two bodies of theory and research: on the one hand regional science, with its interest in explaining local distribution and policy impact of regional high tech industry, technology parks, innovation networks and innovation programmes. On the other hand it builds on the growing literature on national systems of innovation. This literature has provided valuable insights in the innovation processes, high-lightening non-linearity and inter-activeness of the process. Furthermore it has introduced the concept of institutional learning (Cooke, 1998, pp. 1-25).

Apparently industrial regions differ so much from one another that it is hard to find one explanatory factor that would explain differences. According to Cooke and Morgan (1994), localised buyer-supplier networks, together with a robust institutional support mechanisms have played a major role in promoting patterns of innovative activity. Furthermore, low transaction costs and high external economies may have contributed to an 'industrial atmosphere' of a centre of industry. Localised patterns of development are first and foremost a social endeavour, in that they create a local order of understanding, trust and reciprocity, which is a collaborative process in which the firm -especially the small firm- depends on the expertise of a wider social constituency in which workforce, suppliers, customers, technical institutes and training bodies play a predominant role. This cooperative arrangement facilitates processes of collective learning and helps to reduce the elements of dynamic uncertainty; these processes allow for a better understanding of the possible outcomes of a firm's decisions (Camagni, 1991, in Cooke and Morgan, 1994).

Ohmae (1996) has chosen a somewhat different perspective on regionalisation of the economy. He has argued that the scope and character of investments, industry and information technology, but also the scope of the customer has broadened so much, that the traditional role of the nation has become superfluous, and sometimes even a hindrance. In his view the engine of economic development is in what he has called 'region-states', geographical units within nations, but also crossing borders between nations, which offer the best scale, scope and opportunities to play a role in the world economy. The emergence, but also the shape of such 'region-states' is not so much the result of state interference, but rather the result of historical coincidence.

2.7.3 Sectoral systems of innovation

With the advent of digital communication technologies, which offer firms hitherto unavailable opportunities to reduce the 'tyranny of distance' by giving them a 'global reach', it might be thought that locational considerations are less important than ever, with one location being much the same as another (Cooke and Morgan, 1994, p. 25). Internationalisation will lead to a world that is becoming much more unified culturally, especially in sectors as semiconductors, aircraft, computers and automobiles (Nelson, 1993, p. 518). Indeed, Carlsson (1994) has argued that the concept of National Systems of Innovations may have great explanatory power, but that it lacks the capacity to explain differences within certain technology areas, especially those with a profound 'international character'.

Analogous to national systems of innovations, he introduced the term 'technological systems (of innovation)'. The concept of technological systems is technology and industry specific. It has been defined as 'a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure' (Carlsson and Stankiewicz, 1991, p. 111). The set of tools to analyse a technological system are also to be found in the national system of innovation-toolbox, although there are also some marked differences. Technological systems are defined by the boundaries of technological fields rather than by national boundaries, and the institutional and cultural environment is analysed from a technological perspective. Also Godoe has argued that the course and direction of innovations in large technological systems are set out by innovative regimes, which have the capacity for coordination, direction and leadership in the creation of many of the radical technological innovations. Following Krasner (1985), she has defined an innovation regime as principles, norms and ideology, rules and decision making procedures forming the actor's expectations and actions in terms of the future development of a technology (Godoe, 2000, pp. 1033-1046). However, both Carlsson and Godoe have acknowledged that these processes are also influenced by national characteristics as they are imposed, for instance in culture, language, decision making and other national characteristics.

Innovations cannot solely be explained as a necessity emerging from particular 'patterns of innovation' (Hughes, 1987), 'technological trajectories' (Dosi, 1988), or 'technological guideposts and avenues' (Sahal, 1985). There is also an element of serendipity. Mokyr (1991, p. 276) has argued that some cultural, scientific or technological ideas catch on, because in some way the suit the needs of society, in much the same way as some mutation are retained by natural selection for permutation. An evolutionary approach towards technological innovation, which appears as the result of chance, genius, serendipity and science, links research activities to the institutional context in which they emerge. That includes technology and technological regimes on the one hand, but national (or regional) innovation systems on the other. Here we follow Godoe who has argued that radical innovations can best be explained as the result of chance, serendipity, genius and science, whereas incremental innovation are explained in terms of necessity, emerging from technological trajectories with strong directions for future developments, and cumulative in the acquisition of problem solving capabilities (Godoe, 2000; Dosi, 1988, p.1128).

Breschi and Malerba (1997, p. 131) have reached beyond the concept of technological system and have delineated the concept of a sectoral system of innovation. Such as system can be defined as that system (group) of firms active in developing and making a sector's products and generating and utilising a sector's technologies. Important in their conception is that they have put the firm at the heart of the analysis, thus putting emphasis on the fact that competition and selection processes involve firms with different capabilities and innovative performances. These processes are not limited to the geographical (national/regional) boundaries of innovative activities. The boundaries of a sectoral system of innovation are endogenous, they emerge from the specific conditions of each sector and may well reach beyond the limits of regions or the nation.

The contribution of sectoral and technological approaches is that they have reached beyond the boundaries of nation states and explain differences from a technological perspective. Standardisation processes for instance, have a particular influence in large technological systems and thus, have dynamism of their own. This may be the case, but it easily neglects that countries have developed considerable strength in one technology area, but have remained weak in others. Technologies are not evenly spread over countries. For instance, Japan appears to be extremely strong in mechatronics, but not in other manufacturing industries such as chemicals and drugs, nor in distribution and other service industries (Imai and Yamazaki, 1992, cited in Carlsson, 1994, p.14). Similar examples can be made for other countries. The technological specialization pattern of countries differs considerably, even between adjacent countries. In the table opposite we have listed the specialization pattern of Belgium, Germany and the Netherlands, based on the number of patens granted in the USA between 1981 and 1987, and it is clear to see that technologies are not evenly spread across countries, even though some technologies have an outspoken international character. These differences and preferences can be explained by history and processes of path dependence, and we will return to that issue in the sections still to come.

	Rank of top five fields of specialization				
	1	2	3	4	5
BE	Agriculture	Paper	Inorganic Chemistry	Weapons	Paint/Petrol
DE	Weapons	Nuclear Physic	Paint/Petrol	Textiles	Organic Chemistry
NL	Foodstuffs	Others	Agriculture	Electronics & Telecom	IT instr

Table 8 *Rank of top five fields of specialization (IPC classes) of Belgium, Germany and the Netherlands, based on patents granted in the USA between 1981 and 1987*
Source Archibugi and Pianta, 1992

Although Carlsson's analysis has reached beyond the typical national characteristics, it is certainly not a global analysis. Indeed, information and communication technologies have shortened the distance between economic actors, but it remains to be seen if this has led to a true 'globalization' in innovation activities. Archibugi and Michie (1997) have raised the question in this context, if globalization and the role of technological infrastructures are well understood. In their view, communication and transport technologies must not be understood as the globalization of technologies, but rather as the technologies of globalization, because these technologies have serviced the increasing global operation of cultural, social and economic life. It is against this background that the degree of globalization must not be over-exaggerated. Patel has argued that the patented inventions of more than 500 of the world's largest enterprises have shown that the vast majority of inventions are developed in the firm's home nation (Patel, 1995, cited in Archibugi and Michie, 1997, p.132). Globalization of markets is not by definition the same as globalization of innovation systems. Lundvall has argued that, while firms get more engaged in international networking, they reinforce domestic relationships even more. At least in some national systems globalizations gets the elements of national systems to draw closer together than the opposite (Lundvall, 1998, p. 17).

The notion that technological fields have their own characteristics is important, but we do not follow Carlsson that these are just cross-border characteristics. We believe that technological fields within countries have distinct differences, strongly influenced by country-specific institutional and meta-institutional factors and by distinct paths of development throughout history. Even though Carlsson's analysis of border-crossing technologies has widened the perspective, it easily neglects that there are differences within the same technology among countries. Problem solving in large technological systems is on the one hand guided by technological parameters, especially those that are largely codified by agreements and international standards. On the other hand these processes are guided by social and cultural concepts, which are usually rather tacit in nature. The nation as a frame of analysis remains important, even in large technological systems.

2.7.5 'Grand designs' or organic growth-patterns?

In previous sections we have discussed two different lines of innovation research.

First we have examined the geographical boundaries of system of innovation. Second, we assessed the relevance of technological systems and sectoral systems that reach beyond geographical borders. Each approach has its own relevance in that it highlights a specific institutional environment under which innovativeness and economic performance can take place. But creating an innovative milieu is more than putting the right elements in place. Castell and Hall have discussed two projects which are a clear example of 'blueprint development'. Both projects were basically designed from the drawing-board. The Cartuja '93 project in Spain aimed at creating an agglomeration of R&D centres and training institutes, excluding all manufacturing on-site, in some of the leading late twentieth-century technologies: computer software, microelectronics, telecommunications, new materials, biotechnology, and renewable energy. The project was planned to use the same site of the Seville Expo '92, where the biggest World Fair ever took place. The second project, Adelaide's Multifunction Polis, is Australian in location, but Japanese in name. It was designed by the Japanese Ministry of International Trade and Industry (MITI) and its ancestry clearly stems from MITI earlier techno polis projects. Adelaide's Multifunction Polis was set up as a multi-functional facility which would incorporate future oriented high technology and leisure facilities and could promote international exchange in the Pacific Region on new industry and lifestyle (Castell and Hall, 1994, pp. 193-221)

However, neither project was very successful and results could only be expected in the long run (if any). The critical question is if projects like these, in which all the necessary building-blocks are brought together along a carefully designed plan, can constitute a true innovative environment. There are reasons to have doubts about the effectiveness of 'grand designs'. Most political and economic actors are not so much interested in the long-term perspectives that ly at the basis of the blueprint development. Techno-dreams can become techno-cities only if governments, business and industry have a vision of the future, want to follow it, and marshal enough political support to endure the speculative moves and political manoeuvres that will undoubtedly try to derail the project for the immediate benefit of shortsighted personal benefit (Castell and Hall, 1994, p. 221). In other words, plans need to have a supportive and sustaining institutional environment to be successful in the long run. Putting the building-blocks together is not sufficient if the glue that holds them together is lacking. This notion deepens our insight in the role of geographic entities. Not the geographic scale is important, but the glue that binds the elements together. This explains why the importance of the institutional structure of a country has not diminished, despite processes of globalization and internationalisation. On the contrary, with the global market, any competitive advantage will bring larger rewards (Archibugi and Michie, 1997). Knowing which elements of the innovation system support or hamper innovativeness will allow one to set out strategies to develop such advantages. This might be in the promotion of certain types of cooperation or in the enhancement of the functioning of advantageous institutional capacities. Knowing the strength and weakness is a prerequisite to set out particular policies to promote innovativeness. Especially in the knowledge-intensive economy it is important to have an unobstructed flow of knowledge, which is supported by an institutional environment that is tailored to the needs of the sector at hand. However, this is not a matter of a 'grand-design', but rather cutting the elements to size so that they seamlessly fit the prevailing institutional pattern.

2.7.5 Path dependence and historical embeddedness

The functioning of an innovation system is highly imbued by past experience and path-dependent trajectories. The notion of path-dependence holds the key claim that specific patterns of timing and sequence matter. Starting from similar conditions, a wide range of social outcomes may be possible. Large consequences may result from relative 'small' or contingent events in the past. Novel designs are never new in all respects; they usually heavily borrow from what has gone before (Nelson and Winter, 1982). This is an important notion because it explains persistent patterns of institutional behaviour, as well as persistent technological patterns. Countries, for instance, tend to hold strong leading positions in certain technologies throughout the years, without developing similar strength in other technologies. Soskice (1998) made a comparison of the innovative performance of Germany and the USA and found basically the same specialization-pattern over a range of years. The relevance of this finding is that countries do not so easily change existing concepts, nor that it is easy to develop new competences in new fields.

The notion that history matters is widely recognised and usually addressed as path-dependence of social processes. The notion of path dependence is generally used but not so well defined in all literatures. Sewell (1996, pp. 262-3) for instance, has suggested a rather broad definition, that: 'what has happened at an earlier point in time will affect the possible outcomes of a sequence of events occurring at a later point in time'. Levi (1997, p. 28) suggested an alternative, more narrow definition: 'that, once a country or region has started down a track, the cost of reversal are very high. There will be other choice points, but the entrenchments of certain institutional arrangements obstruct an easy reversal of the initial choice'. Pierson (2000, p. 252) has followed this conception of path dependence in which preceding steps in a particular direction induce further movements in the same direction, in the idea of increasing returns. In an increasing-returns process, the probability of further steps along the same path increases with each move down that path. This is because the relative benefits of the current activity increase over time, compared to other possible options. Or, put differently, the cost of exit options, or the switching to an alternative technology will rise over time. The increasing return process is, thus, a self-reinforcing or positive feedback process with some intriguing characteristics, which Arthur (1994) has summarised as follows:

- Unpredictability. Historical events have a large effect, but, as they are partly random, many outcomes may be possible. One can not predict ahead of time which of these possible end-states will be reached;
- Inflexibility. The further into the process, the harder it becomes to shift from one path to another;
- Non-ergodicity. Accidental events early in a sequence do not cancel out. They cannot be ignored, because they feed back into future choices. Small events are remembered best;
- Potential path inefficiency. In the long run, the outcome that becomes locked in may generate lower pay offs than a forgone alternative would have.

Pierson, building on Arthur, has argued that four features of a technological system and its social context generate increasing returns. First, large setup- or fixed costs, as they create a high pay-off for further investment. When set-up- or fixed costs are high, individuals and organisations tend to stick to, and identify with that particular option. Second, learning effects appear in the operation of complex systems, which lead to higher returns from continuing use. Moreover, individuals learn how to use the system more effectively, which spurs further innovations in line of the system. Third, coordination effects occur when the benefits that an individual receives, increase with others adopting the same option. In other words, if technologies embody positive network externalities, then a given technology will become more attractive if more people tend to use

> Volkswagen is the classical example for a company that was locked in in its technology. The Volkswagen beetle has been a tremendous success in the postwar years. Its concept of a flat chassis with the engine in the back of the car has been used in virtually every model, from sports-car (Karmann-Ghia) to transporter and the typical Kübelwagen. However, when the beetle-model was outdated, the engineers had to develop a new model, which was the 412. However, instead of changing the concept, as most car-industries had done before, Volkswagen was loyal to its initial success and again designed a car with the engine in the back. The 412 was an instant failure.

Box 6 *The risk of lock-in: Volkswagen's example of the 412 model* that particular technology. Fourth, adaptive expectations appear when people are in doubt about the choices they have made. If they have to choose another path, they tend to 'pick the right horse' and stick to their choice. There is an element of self-fulfillingness in this choice, because projection about future expectations leads individuals to adapt their actions in ways that help to make those expectations come true (Arthur, 1994, pp. 112-3; Pierson, 2000, p.254).

However, path-dependence also entails the risk of lock-in. This is especially the case when a country is strong in a certain technology and persists in that concept, even when the underlying technology has changed dramatically. The notion of path dependence indicates that history matters and an analysis of a system of innovation should include this element.

What goes for patterns of innovativeness, also goes for the institutional environment. In the agricultural sector for instance, a community of interest has evolved throughout the years, which is often addressed as 'het groene front' (the green front). Farmers, agricultural commodity boards, research institutes and education institutes, but also financial institutes like banks and insurance companies are alle involved in a complex network of intertwined relations. This network has been able to mobilize considerable forces to defend their social and economic interests and to develop a desired direction for further development. For a good understanding of the innovativeness in agriculture it is important to analyse the contribution of this particular institutional setup, in order to understand why the Netherlands has had such a prominent place among European countries in early biotech research.

The institutional setup of the telecommunication sector has developed in the same nation state, but it has developed other, sector-specific characteristics. Our aim is to analyse how the institutional dimension has affected innovativeness in this sector, and how the interplay of organisations and institutes within each sector have led to social arrangements which have influenced the country's innovative performance.

Related to concept of path dependence is the idea that actors operate within the limits of bounded rationality. They observe, conceptualise, and digest information in different ways according to the social rules of the sector in which they operate. An actor does not take all possible options in consideration when s/he has to decide in a particular matter. Instead, s/he makes shortcuts, rounds-off corners and falls back to concepts that have proven their usefulness in the past. Agents have developed a signalling device for the fast processing of information. To keep a tight grip on what is going on in the environment, and to make repetitive decisions easier, people tend to develop routines. Routine is integral both to the continuity of the personality of the agent, as s/he moves along the path of daily activity, as well as to the continuity of the institutions of society, which are such only through their continued reproduction (Giddens, 1984, p. 60). Thus, routines are the basic elements in a process of structuration and provide the capacity for rational evaluation to novel or non-standardised issues. Emotions serve to set the agenda for attention; through emotion, danger calls the attention of rational evaluation (cf. Simon, 1983). In routines agents expose a preference for accepted practice and concepts and they tend to stick to known procedures and decisions, thus providing the system with a high degree of stability and predictability. But routines also entail a risk. If routines becomes a second nature it will be very hard to deviate from them even if conditions require so (Nooteboom, 1999), and, as Nelson and Winter have argued, innovation is basically a deviation from routine behaviour (Nelson and Winter, 1982, p. 41). Thus, there will always be a tension between experimenting with new concepts, new angles and new perspectives on the one hand, and the attractions of known trajectories and known solutions on the other.

2.7.6 National-sectoral systems of innovations

We return to the question that we posed at the end of section 2.7.1. Is the nation-state the best unit of analysis for innovation research, or should we consider another level of analysis, for instance along the concepts of technological systems or sectoral systems of innovation? We will argue that an analysis should include both two elements, nation-specific elements next to sector-specific elements. The question is not whether to choose a national or a sectoral perspective, but rather how to combine these elements in an encompassing national-sectoral analysis. The strength of the national system of innovation approach is that the activities are studied and explored within the social, economical and institutional fabric in which they emerge. Especially the processes which nurture and disseminate technological change involves a complex web of interactions among a range of different subjects and institutions (David and Foray, 1995; Smith 1995). One can map these interactions by studying both market and non-market relations. Individuals learn and imitate, and know-how is often exchanged informally and voluntarily (Von Hippel, 1987). Information can take the form of eighter tangible and intangible assets (Pavitt, 1984), and involves business, industry, but also public institutions, such as universities, research centres, bridging institutions and other arrangements to promote innovativeness (Nelson, 1987). Thus, the strength of the national system of innovation approach is its comprehensiveness, especially its emphasis on how the institutional environment influences and supervises interactions among actors. However, the national system of innovation approach has two distinct weaknesses. First, its risk to hang country-specific differences on case-studies, based on different economical sectors. This is especially the case if the sector studied in one sector has typical local boundaries in innovative activities, which involve a high degree complexity and tacit knowledge, whereas a sector studied in another country may have global knowledge boundaries, which involve highly codified and relative simple knowledge. Such a comparison would not make much sense. It is ridiculous to compare the computer mainframe industry in one country with the textiles-sector in another country and expect meaningful differences between the two countries. Second, national systems of innovation have difficulty in grasping the dynamism of large technological systems and industries. This is especially the case with technologies in which the knowledge, needed to innovate is complex, rapidly changing, specialised and codified. Innovations in these technologies may be located in the country or around the world. Knowledge can be easily transferred trough highly mobile and reliable means, ranging from licences to technology alliances, such as for instance in the case in telecommunications and pharmaceuticals (Breschi and Malerba, 1997, p. 142). These latter types of technologies have had a considerable influence on the innovative performance, especially of smaller countries, which lack the scope, size and funds for a leading performance. After all, technologies are not equally dispersed over countries. On the contrary, the dynamic developments of recent years give reason to believe that many large and generic technologies have fallen subject to international and global technological trajectories. Technological leadership is increasingly concentrating in only few leading countries which have the ambition, size, scope and resources to organise research activities in most efficient ways. As a result of this process the smaller countries, which lack these advantages are relegated to play a role as technology followers, and at best, these countries can become successful niche players (cf. van Tulder, 1988).

This, then, would call for a sectoral approach, able to unfold the dynamism of encompassing technological systems. However, such an approach would easily ignore the institutional environment in which innovative activities take place. The contribution of individual countries to large, generic technology systems cannot be measured along the same ruler. We must always keep in mind that there is still a nation-specific element in such an approach. No matter the scale of technological systems, activities in a certain country are always governed by a country-specific institutional environment. People's grasp of problems and solutions, the way how they communicate and cooperate is imbued by the institutional environment. Some countries have a much more risk-adverse attitude than other countries, and this is reflected in the innovative performance. It is not very likely that a risk-adverse country will take the lead in technological development and will come up with some radical innovations. It is much more likely to expect such a country to contribute to the technological system with small, incremental innovations. Thus, if one ignores nation-specific, or sector-specific elements, one would only grasp half the picture. In order to understand the full dynamism of innovative and economic performance, we should include country-specific elements, as well as sector-specific elements in the analysis.

In our view, the nation is a most significant level of aggregation, because it shapes the basic institutional environment in which innovative behaviour takes place. However, the sector is the second, equally important level of aggregation. Economical sectors within a country may have a different kind of dynamism. Within the general institutional and organizational environment of the nation state, sectors may have different preferences, traditions, history and norms, which usually reflect dominant paths of development, whether societal or technological. Countries, but also industrial sectors can exhibit enduring patterns of behaviour, and enduring patterns of innovativeness. Novelty and innovations are usually not entirely new, but usually built on the collective memory, which has developed over a range of years as the result of sector-specific learning processes. This ‘collective memory’ is embodied in routines, shortcuts and habits which have helped to cope with the complexity of everyday’s life and which often has developed as far as a second nature. Thus, our approach is based on an analysis of country- as well as sector-specific elements. Our frame of analysis is the national-sectoral system of innovation.

We intend to substantiate our argument by building up a table in which we will depict the similarities and differences, the stability and changes over time. The structure of the table is such that it follows the research questions. The structure of the chapters in this study, also largely follows the structure of the table.

				Tele-communication				***Agriculture/ food/ chemistry cluster***			
				1910	***1940***	***1970***	***2000***	***1910***	***1940***	***1970***	***2000***
A *Technology*	*Type of innovations*										
	Scope										
	Leader or follower (in international comparison)										
B *Organizational architecture of the idea-innovation chain*	*Differen-tiation*	*vertical*									
		horizontal									
	Division of labour										
	Mutual dependency										
	Coordina-tion	*within the company*									
		between companies									
		Mobility of	*workers*								
			staff & management								
C *Institutional environment*	*Social embeddedness*										
	'Supply' of skilled labour										
	Education										
	Research funding										
	Impact of regulations										
	Role of the associations in the provision of	*Training & Education*									
		Finance									
		Regulations									
D *Sector characteristics*	*Openness*										
	Cluster characteristics										
	Economic dynamism										
	Market										
	Players in the market										
	External relations										
	Pattern of specialization										

Table 9 A profile for similarities and differences over time and between sectors

The table has four main subjects, indicated by the letters A, B, C and D. These main subjects are closely connected to our first research question, and discuss the typical features of the national-sectoral system of innovation in Dutch telecommunication and biotechnology, regarding technology, the organizational architecture of the idea-innovation chain, the institutional environment and the sectoral patterns of specialization?

In technology we are firstly interested in the type of innovation, and we will use the systems introduced in section 2.1.3 to classify the types of innovations that are brought about in the two sectors under review. Secondly, we are interested in the scope of the innovative activities and we will use geographical entities to classify them (local, national, international, global. Thirdly, we will characterize the sectors' contribution as being a technological leader or follower.

	Telecom ←				→ **Biotech**			
	1910	*1940*	*1970*	*2000*	*1910*	*1940*	*1970*	*2000*
A *Technology*								
B *Organizational architecture*								
C *Institutional environment*								
D *Sector characteristics*								

Highlighting the typical features of the sectors

Table 10 *Differences between sectors*

The organizational architecture of the idea-innovation chain is on the one hand ruled by differentiation and systems for the division of labour, and on the other by systems to coordinate the activities.

Regarding differentiation we make a distinction between vertical and horizontal differentiation. Vertical differentiation refers to the degree of complexity between different idea-innovation chains, necessary to produce a certain product. A product might involve an extremely complex interplay of components and semi-finished products, before it can reach the market, while other products are relatively simple to design and to produce. Horizontal differentiation refers to the phases and how they are linked in the idea-innovation chain. They may be highly separated, as in the old linear models of innovation where a project is only handed over to the next player in line, when the fist has finished his/her work, or rather connected such in the interactive or coupling models in innovation. Closely connected to this theme is the division of labour. This may be relatively simple, with only few players in transparent systems, or rather complex with complicated systems of interactions and adjustment between the players. All these elements result in a specific kind of mutual dependence between the players. We discussed this theme extensively in section 2.4.3, and we will use the terms from the general classification scheme (sequential, flexible improvisation). The second set of questions concentrates on the coordination of research activities. We are interested in how activities are coordinated within the company and between companies. We will use the hierarchy, the market and the network as the typical coordination mechanisms. Furthermore we will concentrate on the mobility of workers, staff and management, because mobility enables an easy exchange of knowledge along the idea-innovation chain.

The institutional environment may be a strong influence. First, we are interested in the embeddedness of innovative activities in the broader societal environment. Innovativeness may be broadly connected to the social environment, or rather narrow. Second, education is an important influence. We will examen if the education system is able to supply the innovation chain with skilled labour, and how education activities are connected to the sector or companies. A third important influence is research funding. Who supplies the innovation chain with research money? Here we are especially interested if money is supplied from the public or the private hand. The impact of regulations is a fourth element to consider. Does it hamper or restrict innovativeness? The fifth element is the influence of associations. Do they have a supportive role in education, the provision of research money or in regulation?

The fourth main subject of the table covers the sectoral characteristics. Here we examine if the system of research activities is closed, or rather open with mutual ties to its environment. We also consider if the cluster characteristics are broad, with many variations in products and/or services, or rather narrow. We also will characterise the economic dynamism. Some sectors are highly subservient to other sectors, while other sectors have dynamism of their own. Furthermore, are the markets open or rather protected? We will count if only few or numerous players are involved in the idea-innovation chain and how many external relations the players have. Finally, we will characterise the pattern of specialization

	Telecom				**Biotech**			
	1910	*1940*	*1970*	*2000*	*1910*	*1940*	*1970*	*2000*
A *Technology*								
B *Organizational architecture*								
C *Institutional environment*								
D *Sector characteristics*								

Table 11 *Systemic coherence within sectors*

The first research question is particularly aiming at detecting the distinctive features of the sectors under review. The second question tries to find out if there is any systematic coherence in the system, in other words, is what we present as a system, indeed a system? Here the focus is on the coherence within each column. For instance, if we find that the coordination between companies takes place in networks, we expect to find numerous actors and external relations, a broad social embeddedness and a large degree of openness. Thus, we try to find out if the elements of the system have an internal, logical coherence, that points at the existence of over-arching organizational systems.

	Telecom				**Biotech**			
	1910	*1940*	*1970*	*2000*	*1910*	*1940*	*1970*	*2000*
A *Technology*								
B *Organizational architecture*	→	→	→	→	→	→	→	→
C *Institutional environment*								
D *Sector characteristics*								

Table 12 *Persistence of patterns over time*

In the columns of the table we try to capture the typical characteristics of the two sectors under review, especially how they develop over time. Each column represents the state-of-the-art in the sectors at a certain point in time. If one reads a full row, one can see to what extent the patterns of specialization are maintained by the organizational and institutional elements of the national-sectoral system of innovation. Here we use a rather broad time-perspective, almost covering a whole century. The choice of periods largely follows the chapters of this study. Our chapter four will portray the early developments in the two sectors until World War II. Chapter five will discuss the post-war developments until nineteen seventy. Chapters six and seven will focus on the organizational architecture in each sector, while chapter eight will elaborate on the institutional environment of the idea-innovation chain. In chapter nine we can finally complete the table and draw conclusions.

		Telecom				**Biotech**			
		1910	*1940*	*1970*	*2000*	*1910*	*1940*	*1970*	*2000*
A	*Technology*								
B	*Organizational architecture*								
C	*Institutional environment*								
D	*Sector characteristics*								

Table 13 *Differences induced by the change of the technological paradigm*

One can read a full row at a time to see how characteristics have changed over time. However, one can also take a narrower perspective to see if there are significant changes between the first three time periods and the last. These changes can be induced by the change of the technological paradigm that has taken place during the last period. It enables us to se how the sectors have reacted to radical change, especially in their future specialization pattern, the organisation of the idea-innovation chain and the institutional environment.

This leads us back to the initial question: Do national-sectoral systems **exist** and **do they matter**? If our research reveals that there are differences between the two sectors, than the concept of national-sectoral systems is indeed relevant. Furthermore, if these sectoral characteristics have a certain logic and systemic coherence, and when they are relatively stable over time, it strengthens the relevance of this concept.

2.8 Conclusion

Turning an invention into a commercial success is challenging, and the engine of a country's competitiveness. The success stories of real innovative people are still intriguing. Why is it that some inventors have been so successful, while others have failed? Is it a lack of talent, a lack of determination, drive, or is it sheer luck? Why is it that some countries, time and time again have created totally new products and industries, while other countries rarely have created either? But also, why is it that some sectors have the fruits of innovativeness, while others have deteriorated? There is obvious no singe answer to these questions; it is rather a complicated puzzle of country-specific and sector- specific elements. As Archibugi and Michie already have noted, the most fruitful lesson in gained by recent research is that innovations and technological change should be explored within the social fabric in which innovative activities are actually developed and used (Archibugi and Michie, 1997, p.122). The process that nurtures and disseminates innovation involves a complex network of interactions among a range of different actors, organisations, institutes and institutions.

The national system of innovation approach tries to encompass all these elements in the analysis. This approach focusses on the interactions between the main players, and how these interactions are influenced by institutions and institutional arrangements.

This has proven to be a very promising line of research and many researchers and policy makers have accepted it with open arms. It helped governments to understand changes in the knowledge-based economy. It starts from the recognition that the competitiveness of firms increasingly depends on their ability to innovate. Many governments have encouraged the exploration of promising, yet uncertain areas of science and technologies, and have supported research and education in these fields.

A second important result of the (national) system of innovation approach is that the principles of the learning society are better understood. Learning requires increased cooperation between academia, and business and industry. Learning promotes interaction and institutional learning between vocational/technical and academic studies on the one hand, and business/industry on the other.

A better understanding of the complex process of innovations has also stressed the importance of small and medium sized companies (SME) for the innovative viability of a country. Governments increasingly try to remove the bottle-necks which SME's encounter. They design policies to provide easier access to finance, technology and innovations, the development of human resources and management capabilities, the promotion of networks, ventures and alliances, and the diffusion of best practices. In the perspective of increasing internationalisation and globalization, governments reduce unnecessary public-sector interventions and deploy their influences in establishing an infrastructure that is encouraging flexibility, innovation and competition (cf. Bartzokas, 2000, p.13). Thus, the (national) system of innovation approach has 'landed safely' in policy circles.

This is surprising, because the national system of innovation approach lacks a solid theoretical foundation. It acknowledges that organizational and institutional factors matter, especially in the interaction between those two levels, but it does not explain how. Thus, measuring the constituting elements of the system is extremely difficult and the strength of the approach is rather in the narrative than in the modelling.

The strength of the (national) system of innovation approach is that it reaches beyond the boundaries of scientific discipline and tries to integrate several theoretical perspectives. Learning theories, new growth theory and evolutionary perspectives are combined in new ways. In this context Dalum, Johnson and Lundvall (1992, p. 299) have argued that many important institutional innovations are self grown. They are not the result of a conscious design, but rather appear as the unplanned result from human actions. But even if innovation is accompanied by risk and uncertainty, the evolution of knowledge is cumulative and often developing along general technological trajectories which may remain quite stable over long periods of time. The (national) systems of innovation approach may lack overall-predictability, it certainly has helped governments to identify the strength and weakness of a given economic system. Furthermore, it provides at least some elementary tools for comparison and this is most relevant in the design of science and technology policy.

The system of innovation approach has basically evolved from the introduction of the concept of techno-economic paradigms by Freeman and Dosi (1988) in the nineteen eighties, which was one of the first attempts by evolutionary theorists to include institutional arrangements in the analysis. The relevance of institutional arrangements is that they regulate the interaction of an economic system. Bartzokas has summarised the main argument of this approach: the need for change is being introduced to the economic system either through changing demand patterns or through technological breakthroughs. But, what determines an efficient adjustment and what promotes growth and welfare at the end of the day, is the way in which institutions adjust to the changes (Bartzokas, 2000, p. 4, emphasis added). That is the focus of this research project. However, describing the constituting elements of a 'system of innovation' is still extremely difficult. As Bartzokas has argued, a methodology to measure the interplay of institutions and change in the economy is still lacking. This is not so much caused by a lack of methodological tools as well as by the nature of the innovation process. He recalls Veblen who has stated that 'change' is by hypothesis a unique event, caused by an indefinite number of causes.

Also Nelson, in his concluding chapter of his study on national innovations systems, has argued that it is extremely difficult to generalise from a 'system of innovation' approach. The national system of innovation concept is not something consciously built and designed, but rather a set of institutional actors who play a major role in influencing economic performance (Nelson 1993). In the same line of reasoning Lundvall has emphasised that the definition of the system of innovation should be open and flexible, regarding which subsystems should be included and which processes should be studied. It follows that we cannot insist upon one single approach to the national system of innovation as the only legitimate one (Lundvall, 1992, p.13). The literatures on innovation systems are divers and different scholars have approached the phenomenon along different tracks. There is not one standard reference and there are important nuances in the interpretation of the concept among leading scholars (Lundvall, 1998).

In his discussion of the different approaches of innovation systems, Edquist (1997, pp. 14-5) has concluded that most of the authors agree on the core determinants of the innovation system approach, but still are rather vague about the boundaries of the system. It is clear that economical, social, political, organizational, institutional and other factors influence the development, diffusion and use of innovations, but, at the present state of the art, defining the limits of a system of innovation, including all determinants and boundaries, is a 'catch 22' problem. Thus, the (national) system of innovation approach is rather a conceptual framework than a formal theory. It does not provide convincing propositions as regards established and stable relations between variables. It is a kind of 'wide trawl' intended to capture processes of innovation, their determinants and some of their consequences in a useful way.

A similar argument was made by Niosi who stated that, although the term is widely used now, its semantic content and operational underpinnings are still vague, and its links with more established concepts are less than clear (Niosi et al., 1993, p. 208). Also Miettinen (2000) has posed the question if the national system of innovation approach is to be regarded to be a research-concept or rather an ideology? However, despite the critique, the concept has gained a pivotal position, not because it provides a good measurement tool, but rather because the narrative that is in the approach has large explanatory power.

If we have the ambition to make a contribution to that body of knowledge, it is exactly in that particular field. Therefore we have built an analytic, multilevel framework which outlines the relations between the organizational, institutional and cultural dimensions. Our task is to fill the boxes in the organizational dimension and explain what changes have taken place over time in the two sectors under review, that both have faced considerable technological change in recent years. We expect to find that complexity has increased. Technologies that originally were developed for one specific field of application have proven to be applicable in many other fields, thus changing specific technologies into generic technologies. This has especially been the case in high tech sectors. Furthermore, the life-cycle of products has decreased which has put pressure on production processes. No longer do workers have the time to internalise technologies; as soon as they have adjusted to one production process, the process of change demands to make room for another product. Flexibility and learning skills have become crucial assets in the work force.

If the strength of the system of innovation approach is in the narrative, than developments should be traced back in time to understand why a given situation has come to being and why the institutional structure has developed as it has done. Secondly, the purely national perspective is too broad in our view, because neglects sector-specific differences. However, a purely sectoral approach is just as little fruitful, because it neglects that innovative behaviour and interactions are embedded in a nation-specific environment. The patterns of innovativeness differ between industrial sectors. Technologies in one sector may be generated within the walls of public research institutes and universities, while in others sectors they are the result from industrial research. Some sectors have grown strong from a range of incremental innovations, while others sectors are characterised by radical innovations which have the capacity to turn a sector upside down. Indeed there will be general traits which a true national in nature, but our interest is to find out if and how technological sectors deviate from and within the national characteristics. We will employ the toolbox of the 'national system of innovation' approach in a national-sectoral system of innovation to bring these differences to the surface.

Chapter 3: Innovation in science-based technologies

3.1 Introduction

The principal aim of this research project is to unfold the national-sectoral system of innovation into its constituent elements and to find out how the elements are related to each other. We are especially interested to find out to identify sectoral variations within the broader framework of national system of innovation and we have chosen to concentrate our research on two science-based sectors, which both have experienced a radical shift of the technological paradigm in recent years, namely the telecommunication and biotech sector.

What is, then, the specific pattern of technological specialization in the biotech and telecommunication sector? Is there a distinct pattern of specialization in the Netherlands, different from other countries? Has it a broad orientation, or is it rather concentrating in some (economically) promising niches? These questions will be discussed extensively in the chapters still to come. Each of these chapters will discuss a historical episode in the technological development of the two sectors. Chapter four will highlight early developments from the mid-nineteenth century to the mid-twentieth century. Chapter five will focus on restoration and modernisation of the post-war era and the focus in the chapters six and seven is on the changes which are brought about by the change of the technological paradigm.

This chapter is -more or less- a technological intermezzo. It provides a guided tour along the most relevant technologies in both sectors. The aim of this chapter is to familiarize the reader with the technological principles of both sectors, and it is especially written for the layman who is interested in the innovation processes which have taken place in both sectors.

In this chapter we will discuss the major characteristics of the technologies at hand and also discuss the most important changes that have taken place in recent years. In the telecommunication section we will especially highlight the main characteristics of the change of the technological paradigm and explain the differences between the old electromechanical (analogue) systems and the modern digital systems. We also will discuss the technologies that go along with that change in transmission technology, in switching and in end-user equipment. In biotechnology section we will basically do the same. After a general introduction in the origins of biotechnology, we will focus on the most important fields of application, such as in healthcare, plant breeding, animal breeding, food industry, fine chemicals and environmental care.

But first we will discuss the major characteristics of science-based technologies.

3.2 Science-based technologies

Why does the study focus so strongly on science-based technologies? The answer is obvious; changes in telecommunication and biotechnology are usually sparked by scientific efforts, and -as discussed in previous chapters- science and knowledge are the key-element of the innovation process in both technologies. But what is more, the changes in both technologies have touched upon each phase of the idea-innovation chain from basic research to marketing, sales and after-sales and brought about changes in the organisation of innovative activities.

In the graph below we have, building on the work of Grupp, listed technologies to the relative science reference indices.

	Technology field	Index		Technology field	Index

Above average	Biotechnology	81	*Below average*	Nuclear technology	-1
	Pharmaceuticals	66		Polymers	-5
	Semiconductors	61		Electrical engineering	-12
	Organic chemistry	58		Environmental technology	-27
	Food chemistry	52		Materials processing	-33
	Data processing	37		Chemical engineering	-34
	Optics	36		Machine tools	-44
	Audiovisual technology	30		Food processing	-46
	Telecommunications	29		Engines	-57
	Materials	28		Handling, printing	-63
	Control technology	20		Thermal processes	-64
	Basic materials technology	15		Medical technology	-67
	Surface technology	9		Space technology	-78
				Transport	-78
				Mechanical elements	-84
				Consumer goods	-87
				Civil engineering	-91

Table 14 *Relationship of technology fields to science, measured by the relative science reference indices at the European Patent Office for 1989 - 1992*
Source: Grupp et al., 1995

The generation of knowledge, its transfer and diffusion in industry have been increasingly important for a country's economic development. The US is the best example of a country that has started to build up close relations between industry and academia early in the twentieth century, especially in the field of defence and related industry. Entrepreneurial scientists like Vannevar Bush and his colleagues at MIT introduced the principle of utilizing revenues from patent licencing to fund new research projects (Saxenian, 1995; Etzkowitz, 2000). As a result the domains of industry and science, which used to be separated fields, were gradually moving towards each other and mutually benefited from joint research projects. Especially during and after World War II, science and industry have strengthened their mutual relations, not only in the US, but also in the European countries. High-tech industries were developed, often building on the platform of close relations between academia and industry.

Initially the term 'high-tech' was used as the denominator for the emerging electronics industry, but with the emergence of similar dense relations in other scientific fields the broader term 'science-based industries' was introduced. The distinguishing feature of high-tech firms is that a significant part of their knowledge-base lies not inside the firm itself and other firms, but in universities and public research institutes (Fransman, 2001, p. 264).

Pavitt (1984) was among the first to be more precise about what exactly should be categorised as science based sectors, thus reaching further than a sense of common understanding. He examined firm-structures in several industrial sectors and traced the flows of products and knowledge within and between sectors. In his analysis science-based firms are especially to be found in electronics, organic chemistry (partly), pharmaceuticals and biotechnology, aerospace, and military technology.

Grupp and Schmoch (1992 a, b) have built on the work of Narin and Noma (1985), who suggested to take the citation-score of scientific articles in official search reports for patents as an indicator[1]. In this way they found it possible to operationalism the notion of science-based technologies in a more quantitative sense. Science-based technologies are defined as fields with frequent reference to scientific publications (Meyer-Kramer and Schmoch, 1998, p. 836). Grupp and Schmoch have transferred this approach, which was originally developed for the US Patent and Trademark Office, to patent applications at the European Patent Office and applied it to the analysis of patents in thirty major technological fields

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

between 1989 and 1992 (Grupp and Schmoch, 1995). According to this analysis, biotechnology has the highest science-linkage (81), followed by pharmaceuticals (66) and semiconductors (61). Most other fields with indices clearly above the average were related to chemistry and the broad field of information technology. Telecommunication as a specific field of application has a score clearly above the average, but related technologies as data-processing and optics have an even higher score.

Technology areas with indices below the average are generally linked to mechanical engineering and civil engineering, but also to high-tech sectors as nuclear technology, the process industry, instruments, medical technology and consumer-goods. In this project we have confined ourselves to two sectors with a science-base most clearly above the average: telecommunication and biotechnology.

3.3 Telecommunication [2]

Telecommunication is an encompassing sector, covering a range of technologies, industrial products (hardware) and services (software). In this research project we will mainly focus on innovations in telecommunication hardware and especially on switching and transmission equipment. We follow the OECD definition and distinguish between three categories in telecommunication equipment, namely transmission equipment, switching equipment and terminals (OECD, 1983; Roobeek, 1988). Transmission equipment carries the telecommunication signals between terminal stations and switching centres. It involves a broad range of transmission technologies (analogue/digital, multiplexing, modulation, narrowband/broadband) and transmission media (from the simple paired wire to the complex technology of optical fibres and satellites). Switching equipment serves to connect terminal stations and to coordinate entire telecommunications networks from central switching points. Terminal equipment transmits information through the network from one end-user to another. It covers a wide range of equipment, varying from simple telephone sets, sophisticated mobile phones, tele-writers and facsimile equipment to digital private branch exchanges (PABX or business systems).

The telecommunication system used to be a relatively stable system, even though it has been improved time and time again. These were often artisanal and adaptive innovations. Many of the early innovations were brought about by skilled technicians who repeatedly found ways to improve the functioning of the system in processes of learning-by-doing and learning-by-using. These innovations were initially not so much the result of scientific efforts, but rather the result of trial and error on the job. They were rather driven by curiosity than by systematic research. Later, these activities were coordinated in research departments.

Each innovation made in this context has extended the borders of technology, even though the underlying principles were not fully understood. Each innovation has also increased the complexity of the system. Even in the analogue days of telecommunication, the system has a complexity that has equalled the design of a modern aircraft, yet building on a basic set of principles that remained hardly unaffected until the nineteen seventies and eighties. Telephony was, until then, the most important service and for long it was almost used as a synonym for telecommunication. Data-communication, such as in telex and telegraphy, was a much smaller service, although very important especially in the business and industry world, because these documents had a legal status. Yet, especially during the last decades of the twentieth century, telegraphy was marginalised to greetings-telegrams for special occasions and telex-services were mainly used by journalists or businessmen, working in remote areas, or for the transmission of legal documents. However, these classical data-services where overhauled by modern data services, which were rather based on computer technology then on telecommunication technology. While the number of

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[2] In writing these chapters we have build extensively on the work of Dodd (1997) and Nijhof (1999) who wrote in much greater detail about the technological aspects of telecommunication. These sections are partly an excerpt of their work, for which we owe them gratitude. However, for reasons of readability we made no singe references in the text.

telephone connections was about to reach a point of saturation, the demand for these new data-services started to increase.

The introduction of the fax has been an important impulse for the extension of the telephone-network, because it has marked the first convergence of, until then, separate technologies. On the one hand there was the voice-based telephony system and on the other the data-transmission system. The fax-machine combined the features of both technologies and the fax has been an important trailblazer in the development of a new telecommunication system.

Next to the introduction of new technologies, there was also a new type of demand. Especially the service-based economy has boosted the demand for value-added services. Furthermore, new service-providers were allowed onto the market and offered a range of new services. Business was no longer solely dependent on the services of the classical, national PTT monopoly. Furthermore, new digital technologies and increased competition have reduced the cost of the exploitation of telecommunication networks and this has challenged new entrants to step into the telecommunication market. Large multinational companies started to build their own large volume networks, which were used for voice telephony as well as for data-transmission. Dutch PTT tried to ward off this development by extending its network with additional business networks, especially suited for data-transmission.

These turbulent developments were facilitated by a range of important technological innovations which were introduced in the telecommunication network as off the latter half of the 1980's. The most eye-catching development was the prosperous convergence between computer-technology and telecommunication, which has led to the development of a fully digital switch, thus, ruling out the existing technology of electromechanical switches. The main differences between the old analogue system and the new digital system are (i) in the type of signal and (ii) in the switching of the signals. The analogue system was based on the transmission of voice-signals, while a digital system is based on the transmission of binary bits of data, which is the standard in computer-technology. This latter type of signal has only two positions: ‘on’ and ‘off’, whereas the analogue telecommunication signal can have an infinite number of positions within a certain frequency-reach. An analogue signal is much more vulnerable to mistakes, noise and fading.

> An interesting experiment was done in a Dutch radio-advertisement. It was about a product which was half priced and the gimmick of this radio-commercial was that half the text was left out. Some words were only pronounced half, vowels and consonants were ‘swallowed’, and even whole words were left out. Still, the message of the commercial was perfectly clear, even for the not-so-close listener.

Box 7 *‘Getting the picture’ even if the message is poor*

In voice communication this is not much of a problem, because the interaction between persons is not so much affected by cracks or other disturbances on the line. Even if the quality and audibility of the signal are poor, individuals fill in the blanks with their own logic, they repeat words, or ask for confirmation. Voice-communication over the analogue network is possible, even under poor conditions, because the spoken word has its own logic and a certain degree of predictability, based on social patterns of interactions. However, the transmission of data is far more critical than the transmission of the spoken word. Even the slightest mistake can have a tremendous impact on the content of the message. An amount of ten-thousand Euro for instance, is completely different if the separation point has only moved one position. Thus, when it was obvious that the analogue system could not provide the reliability that was demanded for data-transmission, an alternative was sought which was compatible with the binary structure of computer signals, but also could handle voice-communication. This alternative was found in the digitalisation of transmission signals. Voice-communication was transformed into digital signals at the senders’, transmitted through the network as digital signals, and transformed into analogue signals at the receivers’. An additional feature of digital technology was that it allowed for higher speed, more capacity, clearer voice in telephony, fewer errors, less complex peripheral equipment, less maintenance, economy of space, but especially, more reliability, which is especially important in data transmission. Next to these advantages, digital equipment was cheaper.

It is a common law in telecommunication that each transformation of a signal decreases the speed of transmission and is a possible source of failure. The transformation from analogue to digital and back again, is in fact a rather inefficient system. This was especially the case in the early days of digitalisation, when switching was still analogous. The expected increased of speed, stability and reliability of digital signals were largely nullified by the analogue switching systems, no matter their state of sophistication. The classical galvanic connection, which was operated through a system of relays, or contact-breaker points, could not meet the increasing technological demands of digital technology and a new approach in switching was needed. This has resulted in the design of a digital switch which was introduced in the European telecommunication system from 1985. The digital switch is basically a very high-powered computer. The connection between two subscribers is no longer established through a galvanic connection, but through software. This major step in telecommunication technology has opened the door to a range of new services, such as for instance intelligent networks. The term Intelligent Network (IN) does not so much defines a special kind of network, but it is rather a concept that is applicable to all kind of networks. A basic feature of an intelligent network is that it has separated services from the physical infrastructure. With the use of the computers one can, from a central point, implement new services, without changing the physical structure of the network. As a result, intelligent networks can offer a variety of value-added services such as virtual private networks, free call and calling card services.

The introduction of digital switches has cleared the way for improved capacity, fewer errors and higher speeds. However, the capacity of the transmission media was still limited. The classical telecommunication cable was suitable for the transmission of narrowband, analogue signals, but the capacity was too low for the modern digital signals.

Optical technology has brought the solution and has proven to be the 'workhorse' of telecommunication systems. The introduction of optical fibres in the network has caused an explosion of the capacity of the infrastructure and an implosion of user-costs. The graph below illustrates this clearly in a historical overview of the costs and capacity of a trans-Atlantic sea-cable. The costs per unit have dramatically fallen over a period of 44 years. Costs have fallen from 43,000 Euro in 1970 to 5 Euro per single telephone-path in 1970, while the capacity of a single sea-cable has increased in that same period from 1400 to 58 million paths. The increase of capacity is mainly due to technological innovations in optical fibre and transmission technologies. (Ministry of Transport, Pubic Works and Water management, 2000, p. 25)

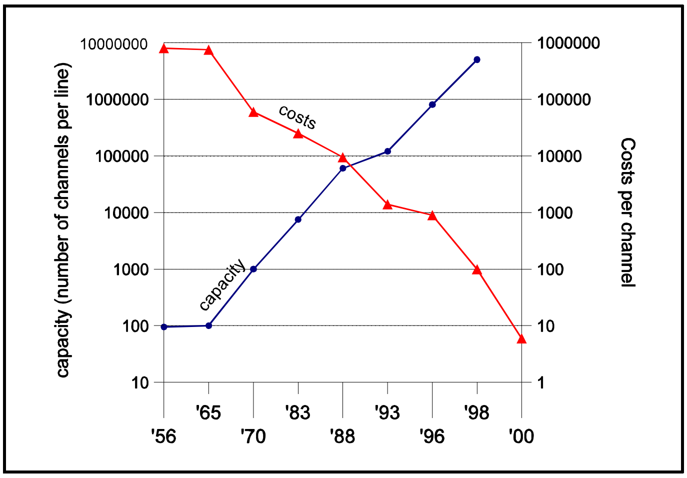

Figure 15 *Capacity and costs telephone-paths in a single sea-cable*
Source: Ministry of V&W, 2000/ TeleGeography, 1999

One of the last obstacles in the current telecommunication infrastructure is the 'last mile' to private subscribers. The analogue connection is well suited for voice-telephony, but is falling short for the increasing demands for capacity in data-transmission, such as the Internet. Private subscribers can digitalise the last mile through the installation of an ISDN modem (Integrated Services Digital Network), with an increased capacity to 144 kbit/s, or an ADSL modem (Asymmetric Digital Subscriber Loop), which has an increased capacity up to 1500 kbit/s. These systems are to be seen as a prelude to the introduction of even faster technologies, as for instance a fully optical connection.

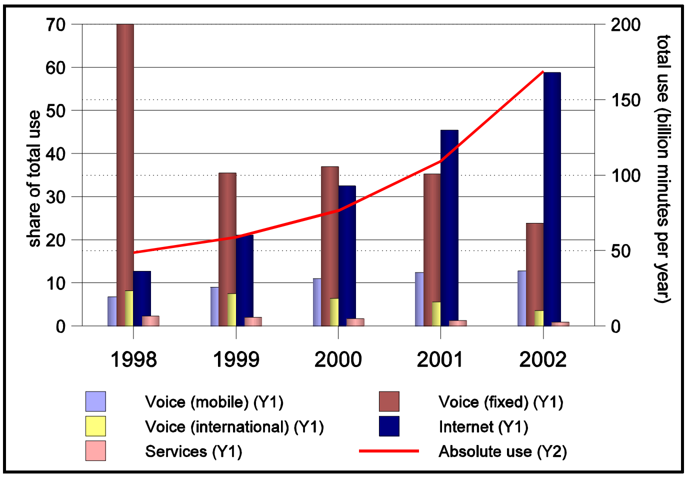

Figure 16 *Development and prognoses for telephone and Internet use in the Netherlands, 1998 - 2002*
Source: Stratix/Opta 1999

The urge for faster systems is increasing, especially through a more extensive use of the Internet. The thick line in the graph above indicates the volume of telecommunication traffic. In 1998 this was 48.7 billion minutes per year, but it is expected that this will grow to 168.8 billion minutes per year in 2002. Thus, the volume will almost triple within five years. The bars in the graph indicate the share of the various services. Voice telephony over the fixed network is clearly dominant in 1998, with 70% of all services, but its dominance is under decline. In 2002 it is expected to have a 23.8% share. Internet-services on the other hand, have only a modest position in 1998, with a share of 12.7%, but by 2002 this is expected to have risen to 58.8%. It is also expected that the average subscriber will spend more time using telecommunication services. In 1998 this was 8.5 minutes per day, but by 2002 it is expected to increase to roughly 29 minutes per day. Thus it is clear to see that the demand for telecommunication services is rising and so is the demand for capacity.

All technologies discussed so far have increased the capacities of the system, however, without reaching its highest peak. Most of the telecommunication signals today are transmitted through the network as light-pulses, but each transformation from electrical signals into light-pulses is a hindrance and a loss of speed and efficiency. Thus, it goes without saying that a fully-optical system will have the best properties for future systems. Optical switches are currently under development and the establishment of an optical connection into every household is high on the priority list of telecom companies. It is not so much the question 'if' this will happen, but rather 'when' it will happen. That is a revolution still to come. The current perspective is a seemingly endless increasing capacity of the telecommunication system.

3.4 Various technological aspects of telecommunication

Telecommunication is basically the transport of signals whereby electromagnetic waves are transmitted through a transmission medium from one end-user to another. We distinguish between guided and unguided transmission. Guided transmission makes use of electrical conductors or optical fibres, whereas unguided transmission is wireless; using the electromagnetic waves of the radio-spectrum. The signals are in both cases made by a sender and received by one or more receivers.

The telecommunication infrastructure is the aggregate of all the telecommunication elements needed for the transmission of signals. It encompasses three basic elements: the transmission-net (cables, optical fibres, satellite connections, and radio beams), switching-nodes, and end-user equipment. Within the infrastructure we can distinguish between several task-oriented networks, such as for instance the telephone network, the telex network, the data-network and the CaTV network for the transmission of television signals.

A network is established, when a specific selection of elements of the infrastructure is put together in one specific design or architecture. Specific devices, such as telephone sets, tele-writers, fax-machines or computers, can be connected to the network, so that the services provided by the network can be used, by private subscribers. These devices are usually addressed as end-user equipment.

In the sections still to come we will discuss some of the most important technological aspects of the telecommunication system in greater detail. The purpose of the discussion is to familiarise the layman-reader with telecommunication technology and the aim is to provide an explanation and overview of the technological terms that will be used throughout this study.

3.4.1 Transmission technology

The classical principle of telephony is that two individual subscribers can communicate using a galvanic connection between two telephone sets. The basic sequence of telecommunication starts with the sender's voice which sets the air to trembling. This signal is picked up by a microphone and transformed into electromagnetic waves. These are transmitted through a medium (wire, or radio waves) and at the receiver's end the electromagnetic signal sets a small loud-speaker in motion, which makes the air tremble. Now the message is audible to ear of the receiver.

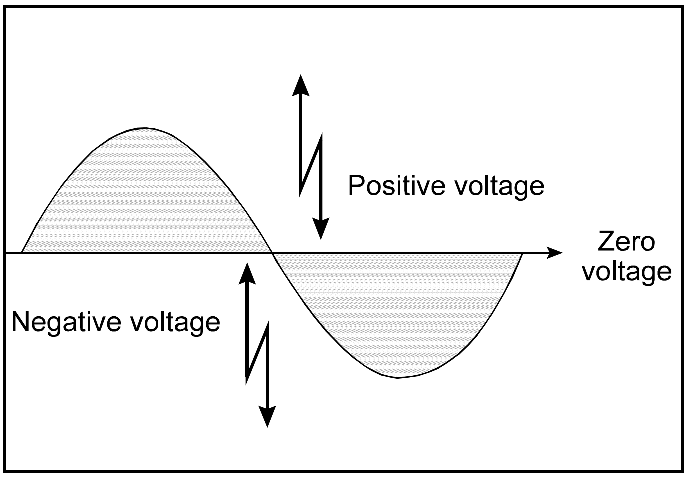

Figure 17 *One cycle of an analogue wave, one hertz (Hz)*

In this very basic example the electromagnetic waves move down the telephone line as analogue signals and their speed is expressed in frequency. Frequency refers to the number of times per seconds that an electromagnetic wave oscillates. A complete cycle occurs when a wave starts at a zero point of voltage, goes to the highest positive point, down to the lowest negative point and then back to zero (as is drawn in the figure opposite). The higher the frequency, the more complete cycles of a wave are completed within a given period of time.

Frequency is stated in hertz (Hz); for instance, ten complete cycles in one second are expressed as 'ten hertz' or 10 Hz. Analogue signals travel within a specified range of frequencies. Voice for instance travels within the 300 to 3300 Hz range. The speed of a particular service is determined by subtracting the lower range from the higher range. Thus, voice travels at the speed of 3000 Hz, or, more commonly 3 KHz (kilohertz). Analogue television at the speed of 706 MHz (megahertz) and analogue microwaves towers at 10 GHz (Gigahertz)

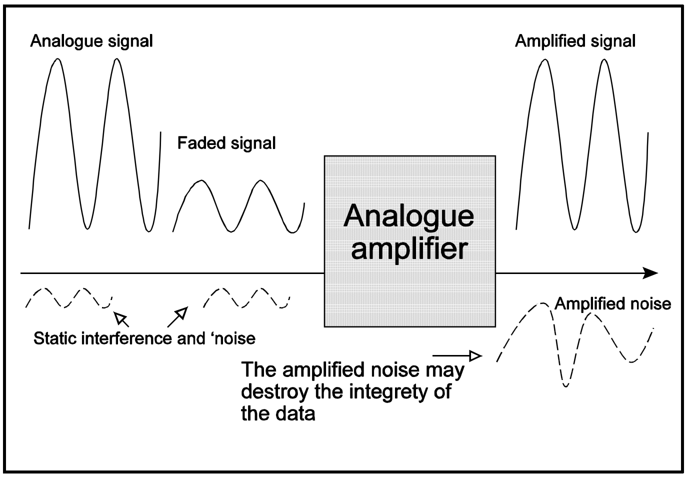

Figure 18 *Noise, amplified with the signal in analogue transmission*
Source: Dodd, 1998

Sending an analogue telephone signal through the network is like sending water through a pipe. Rushing water loses force as it travels through the pipe. The further it travels, the more force and the weaker the stream.

This is the same for the transmission of electromagnetic waves. The analogue signal weakens as it travels over distance, because it meets resistance in the media through which it is transmitted (eg. cable, air). In voice conversation this is heard as a softer voice. In addition to weakening, the signal also picks up electrical 'static' interference, caused by power lines, light and electrical machinery, and these interferences cause 'noise' on the line. In voice communication this is heard as cracking, creaking and static noises. To overcome the problem of the fading signals, an analogue signal is amplified at regular distances. However, this is not without problems; the amplifier cannot tell the difference between the original signal and noise and, thus, both signal and noise are amplified. In voice telecommunication this is not much of a problem, because in general, people can still understand the message, despite the static sounds. But noise on a data-line is much more problematic. When noise on data transmission is amplified, the noise may cause errors in transmission. For instance, in the transmission of financial data, errors might occur and € 12,000 might easily change into € 120,000 or € 1,200.

Digital signals are not transmitted as electromagnetic waves, but transmitted in the form of binary bits. In telecommunication the term binary bit refers to the fact that there are only two values for the transmission of voice and data bits: 'on' and 'off'. Digital signals are better suited for data-communication, but they also give a clearer tone in voice transmission. Yet, the main advantage is that digital signals can easily be recovered in a more reliable way than analogous signals, because it is much more complicated to re-create the analogue electromagnetic waves with their multiple forms, than it is to re-create the simple binary bits.

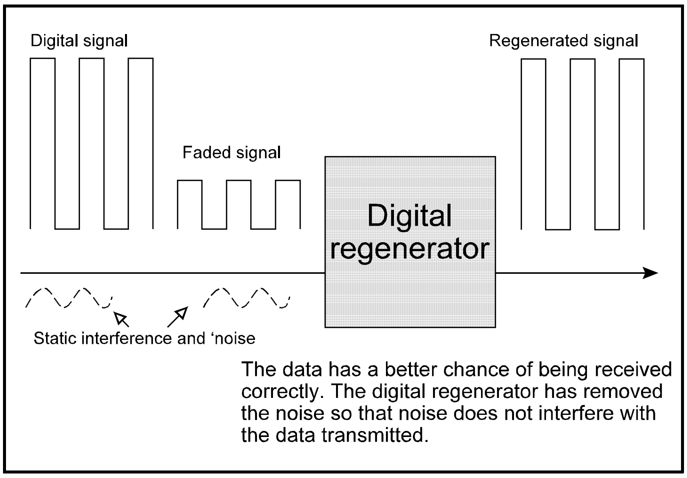

Figure 19 *Digital signals regenerated and amplified, eliminating noise and static from the signal*
Source: Dodd, 1998

A faded 'on' is still 'on' and 'off' is still 'off', no matter how faded the signal. However, just like analogue signals, digital signals are subject to impairment and thus have to be recovered and amplified along the line. However, the main difference is that digital equipment is designed to recognise just 'on' and 'off'. Static and noise are discarded and the resulting signal is much clearer, even when transmitted over large distances.

Clarity and reliability are the main advantages, but they are not the only ones; digital transmission also travels faster than analogue transmissions because digital signals are less complex to transmit. They are either 'on' or 'off' bits, whereas analogue signals take the form of complex waves. The highest speed for analogue modems is 56,000 bits per second, whereas digital signals run at Gigabit per second speed. Furthermore, digital services are much more reliable than analogue ones. Finally, less equipment is needed to boost the signal, because the weakening per distance is much smaller in digital services than in analogue services.

Digital transmission technology was introduced prior to digital switching. This had the disadvantage that digital signals had to be converted to analogue signals before they could be handled by the classical analogue switching-nodes, which was a rather cumbersome procedure. Northern Telecom (Canada) was the first to develop a fully digital switch. It applied this new technology first in business-systems and used the experience build up in these small systems to build the large central office switches. Its first DSM 10 system was installed in Canada in 1977 and in the USA in 1982.

AT&T developed its own version of a digital switch in 1976 to switch calls between central offices. AT&T introduced its 5 ESS system in the USA in 1982. This design was also used in the Netherlands from 1985 onwards.

3.4.2 Bandwidth: narrowband and broadband

The capacity of a telecommunication system is expressed in bandwidth. An important rule of thumb: the large the bandwidth, the larger the amount of information that a signal can carry. Analogue signals bandwidth are measured in Hertz (Hz), while digital signals are measured in bits per second (Bps). Just as more water fits in a wider pipe, broadband lines can carry more information than narrowband lines. For instance, narrowband lines can be used for analogue voice communication (0.3 Mhz), whereas broadband is needed for television broadcasting (6 Mhz) or cable television (700 Mhz). This is an important notion, because the more telecommunication services are integrated (e.g. the Internet), the stronger the need for broadband transmission capacity. Here we touch upon some of the axioms in modern telecommunication. The need for capacity is increasing, which puts high demands on the quality of transmission media. But, the higher the capacity, the more sensitive the signal. A high frequency radio-signal for instance, can severely be disrupted by buildings, trees and even by small objects like rain-drops. It goes without saying that the design of the telecommunication networks should have least obstacles. Each transformation from analogue to digital and back again is a disruption of the flow, and might even harm the signal This is still the case in modern equipment because electrical signals are transformed into optical signals and back again.

Wave-length	**Frequency**	**Radio spectrum**	**Applications**
10 mm	30 GHz	**EHF** extra high freq.	Fixed and mobile services, radionavigation, broadcasting, space travel, radar, inter-satellite transmission
100 mm	3 GHz	**SHF** super high freq.	Broadcasting, fixed and mobile stations for radio-beams, radar, space travel
1 m	300 MHz	**UHF** ultra high freq.	Broadcasting, television, fixed and mobile networks, meteorology, radionavigation, radioastronomy
10 m	30 MHz	**VHF** very high freq.	FM-broadcasting, fixed and mobile services, radionavigation and space travel
100 m	3 MHz	**HF** high freq.	Fixed and mobile services for aviation and shipping, military and meteorology
1 km	300 KHz	**MF** medium freq.	Fixed and mobile services, broadcasting
10 km	30 KHz	**LF** low freq.	Fixed and mobile services, radionavigation, broadcasting
100 km	3 Khz	**VLF** very low freq.	Fixed and mobile services, radio navigation

Table 15 The Radio Spectrum: an overview of the use of the radio-spectrum and the applications for each type of frequency and wavelength, Source: Nijhof, 1999

3.4.3 Architecture and protocols

The term 'telecommunication' was long time used as a synonym for telephony, but this has changed in recent years. Many new devices have been connected to the telecommunication network, like fax-machine and data-processing equipment, like computers. To manage the communication between this broad range of devices, the telecommunication network needs a set of signposts, switching nodes, and a shared language, understood by all types of equipment. The telecommunication network needs its own set of rules to manage the transmission of signals in the infrastructure. These rules decide in matters like:

- Who is to transmits first?
- What if an error occurs?
- Whose turn is it to send data?
- How are messages divided into packages?

More or less related questions are grouped together in sets of rules, the so called 'protocols'. For instance, devices, communicating over the Internet use different protocols for different functions. Several dissimilar protocols are tied together in an architecture, which is a related set of protocols. Usually these architectures are developed by standardisation bodies. The International Standards Organisation (IS) for instance, developed the Open System Interconnection architecture (OSI) to allow devices from multiple vendors to communicate with each other. Even though the OSI architecture is not widely implemented, it has gained importance as a point of reference. The basic concept of OSI is that of layering. Groups of functions are broken up into seven layers. The function of each layer aims to provide a specific service to the next layer, using the services of the previous layer. The layers are (from bottom to top):

Layer 1 is the physical layer. It defines the electrical interface and type of media, e.g. copper cable, radio-waves or optical fibre;

Layer 2 is the data-link layer, which refers to the (LAN) networks which are widely used in businesses enterprises, schools, offices, etc. It provides rules for error control and access to the (company-) network;

Layer 3 is the network layer and contains rules for addresses and a more sophisticated error control;

Layer 4 is the transport layer, that is in charge for an efficient and reliable connection between the end-systems and it is in charge of network quality;

Layer 5 is the session layer and takes care of a smooth working of a dialogue between parties. It also provides reference-points, so that in case of a failure the network-connection is reset from the last reference-point;

Layer 6 is the presentation layer transforms information with a specific syntax into a standardised format. Also, encryption to secure confidentiality of the communication is handled in this layer;

Layer 7 is the application layer, where we find functions as file exchange, e-mail and directory services.

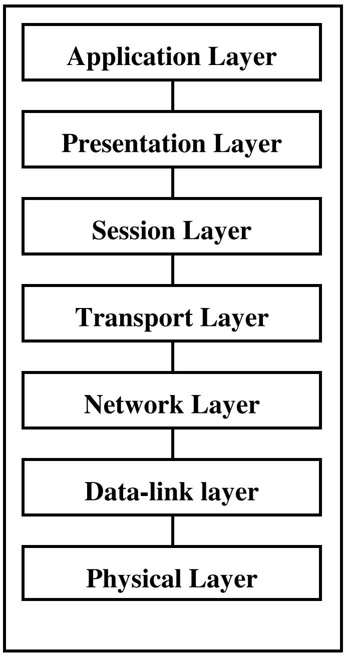

Table 16 *The layered structure of the OSI architecture*

An alternative for the OSI architecture is provided by the Internet Protocols. The core of this architecture is provided by the Internet Protocol (IP) and the Transmission Control Protocol (TPC). An interesting feature of the IP architecture is that it is not developed by an international standardisation body, but by the users of the Internet.

A comparison of the functionality of the IP architecture with the OSI model shows that the lower three layers have quite some similarity to the four lower layers of the OSI model.
However, TPC/IP has not a separate session and presentation, layer. These functions are included in an extended application layer. Even though there are many differences between the architecture, they only serve one purpose and that is to guide telecommunication smoothly through the network. Today, several architectures are in use.

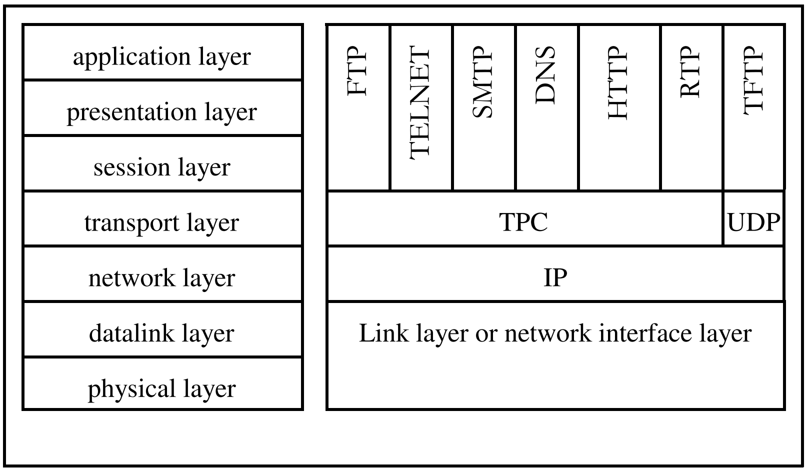

Table 17 *The OSI-model (left) and TCP/IP architecture (right) compared*

3.4.4 Modulation and multiplexing

A classical telephone-call is a rather inefficient way to use the network's capacity. In general, only half of the capacity is used. In general, when one of the end-users is speaking, the other one will just be listening. Thus, only one of the two end-users is actually using the network's capacity. The end-user who is listening is not using the system's capacity. A more efficient way of using the system's capacity could be to transmit another conversation, when the line is not actually used.

The most efficient use of the telecommunication infrastructure is when the full spectrum and full capacity is used for transmission. Telecom engineers have a range of modulation and multiplexing technologies to their disposal to modulate a signal in such a way that 'open spaces' in the network are used most efficiently. One of the many ways is to change the signal from one frequency to another at the senders' and bring it back to the original frequency at the receivers'. Shifting frequencies is possible because each transmission medium has its own traits and limitations, and allows to use band-width in the most efficient way.

The basis for modulation is a sinus-shaped signal with a constant frequency, which is called the carrier, technologically written as $s(t)=A\sin(2\pi ft+\varphi)$. Knowing this, we can vary one or more of the parameters (A amplitude, f frequency or φ phase) proportionally with the signal. In this way the carrier is modulated with the signal. Depending of the parameter used for modulation, one can distinguish between amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM). The result of modulation covers a frequency band on both sides of the carrier frequency. Both sides contain all the information of the original signal and one of the two sides can be filtered out, without losing the original signal. This is called single-sideband modulation and it is used to enhance the capacity of a transmission medium. In this way several signals can be modulated, each to its own carrier frequency and transmitted at the same time through the same medium. This is called stacking or frequency-divided multiplexing.

Modulation, as drawn up in the above, is a technique especially suited for analogue transmission. Modulation of digital signals is a special case, because the carrier frequency is limited to a specific set of values. But again one can vary the three parameters and so we have amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK) as the digital equivalents for analogue modulation technologies.

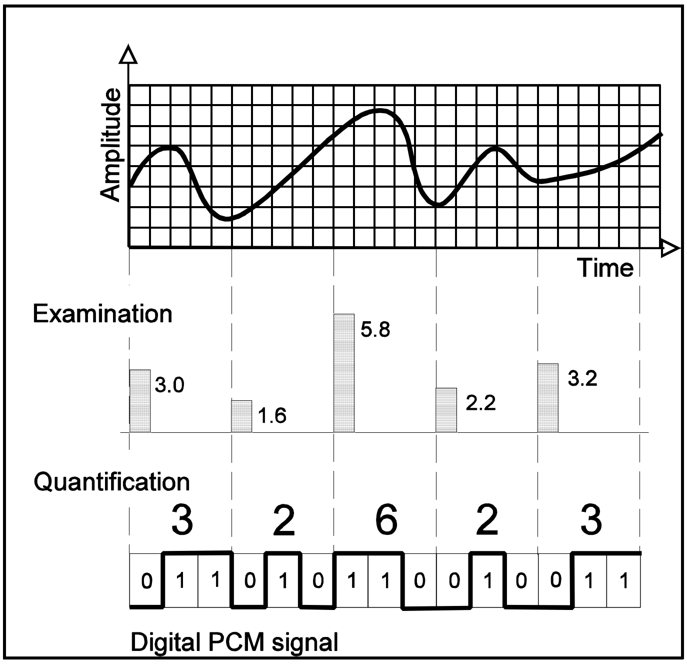

Figure 20 *Pulse Code Modulation*

Pulse code modulation is a special, but most important technology, because it is used to convert an analogue signal into a digital signal. The basic principles are as follows. An analogue signal (the 'wave' in the top of the graph) is examined at regular intervals and from each examination a sample is taken. In the example opposite, each sample is rounded off on a scale of five units (five columns in the matrix). The results are then transposed in a three-bit code and the sequence of these codes form the digital PCM signal. Now the signal is ready for digital transmission. At the receiver's end the signal is translated back into an analogue signal. A small disadvantage of this technology is that the rounding off process causes minor quantification noises, but these are hardly audible.

Pulse code modulation is especially used in telephone networks to change analogue voice signals into digital signals. A range of technologies is used to limit the bandwidth of the voice signal. Usually the frequencies in voice communication are limited from 300 to 3400 Hz, because the range of these frequencies provides good audibility. The filtering process, however, does not cut off sharp frequencies and some additional frequency-space is needed on both sides of the carrier-frequency, so that in practice the voice-telephony has a bandwidth of 4000 Hz. The examination frequency is 8000 Hz. Each sample taken in the pulse code modulation process, is represented in codes of eight bits with which one can distinguish 256 separate levels. The PCM signal travels at a speed of (8000 samples per second) x 8 bits = 64,000 bit/s = 64 kbit/s. Almost all frequencies used in the telephone-network are derived from this particular frequency.

Multiplexing is another technology to use the capacity of the network to the utmost. Multiplexing is basically combining several signals into one signal which is especially suited for transmission. In the de-multiplexer at the receiver's end the signal is transposed into its original signals. Modulation and multiplexing are related technologies to enhance the network's capacity.

3.4.5 Transmission media

Telecommunication signals are transmitted trough transmission media. We distinguish between guided (wires, like twisted copper, coax cable and optical fibres) and unguided (wireless) transmission media. Unguided media are transmitted in free space, such as for instance radio-beam links and satellite connections.

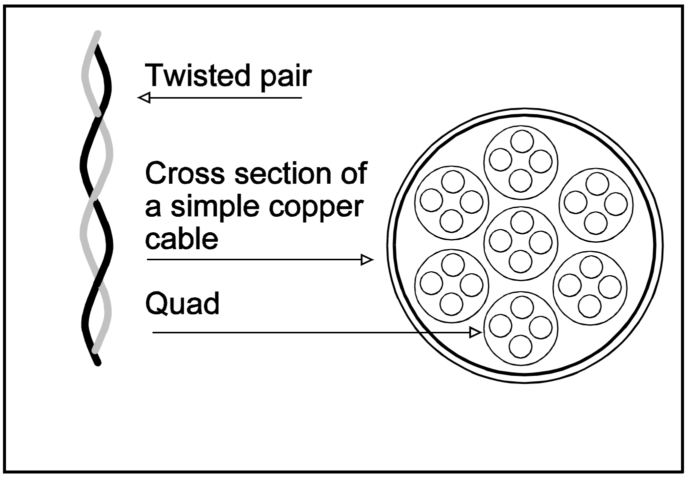

Figure 21 *Twisted pair: simple example (left) and cross section (right)*

Guided transmission media

There are basically two types of guided transmission media for electromagnetic waves: twisted copper wire and coax cable.

Copper wire was the first material that was used in large scale transmission of electro-magnetic signals. A copper cable is composed from one or more twisted cable pairs. A twisted pair is basically a set of two insulated copper-wires which are twisted around each other. In the thick copper telecommunication cables, sets of twisted pairs are joined into small bundles (quads) and these bundles are twisted in a cable. A heavy ground-cable is protected by a steel shield against mechanical injuries and protected by a waterproof shield against water. Until the mid 1980's copper cables were used in the trunk network, but nowadays they are still used in the local loop, that is the distance between the district switchboard and the private subscribers' connection point.

Twisted copper wire does not have the best qualities for telecommunication purposes. It is sensible to interference and it absorbs a relative large amount of energy, so that signals in a copper-cable need to be amplified every few kilometres. Also its bandwidth is limited, depending on the distance to be bridged.

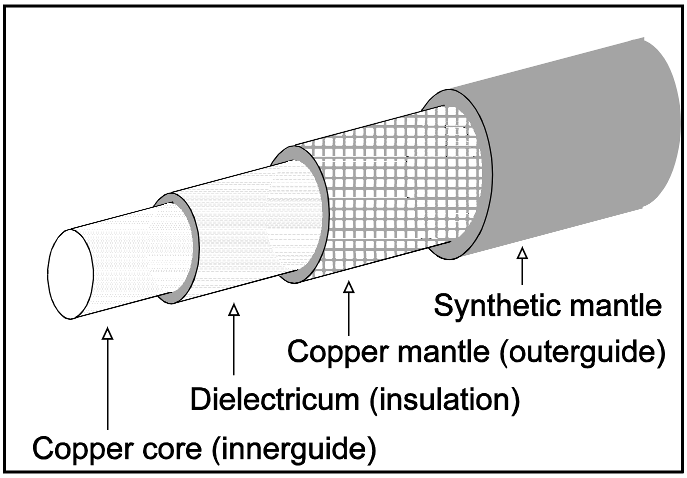

Figure 22 *Coax cable (cross section)*

Coax cable is a special type of copper cable, with much better transmission characteristics than the classical twisted copper cable. A coax cable is a copper core surrounded by a copper mantle. Between core and mantle there is a thick layer of insulation. Just as the twisted copper cable, the coax cable is protected against mechanical damages and damp.

The advantages of a coax cable over a twisted pair are its lower degree of muffling at the same frequence, its bigger frequency range and insensibility for disturbances. For long, coax cable has been a promising technology in telecommunication. However, is not so widely applied because alternative technologies were cheaper (radio waves) or even had even better properties, like optical fibre. It is especially applied in CaTV systems and local area networks (LAN's) because of its excellent bandwidth characteristics.

Optical fibre is also a guided transmission medium, but its technology is different from the ones discussed before. In optical technology the electromagnetic signal is converted into light pulses and these are transmitted in the optical fibre. At the receiver's end of the fibre the signal is converted into electromagnetic waves again. Thus, optical fibres do not transmit electromagnetic waves, but light-pulses.

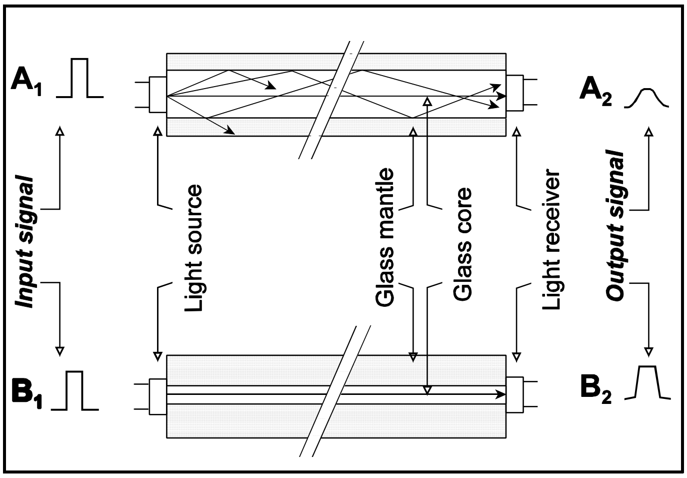

Figure 23 *Optical fibre (cross section of two types)*
A: Multi-mode
B: Mono- or Single mode
Source: van Etten, 1999

An optical-fibre is composed of a glass-core and a glass mantle, both with a different refractive index. As a result, the light pulses in the core of the fibre are reflected and propagated. The optical fibre is insensitive for induction and does not need a mantle of insulation for its performance. However, it is wrapped in coatings and a synthetic mantle to protect the fibre against external damages. Usually one singe cable contains several optical fibres.

There are basically two kinds of optical fibres: multi-mode and mono-mode. The core of the multi-mode fibre has a diameter of 0.05 millimetres. Even though this is thinner than a hair, it is still relatively thick compared to what is needed for the wavelength characteristics of light-pulses. In the transmission process a part of the pulses is bounced around within the core, while another part follows the straighter line though. As a result the light-pulsed at the end are not as sharp as at the beginning (compare A_1 and A_2 in the graph opposite). This is called 'dispersion' and it limits speed and capacity of the fibre. Modern mono-mode optical fibres have a much narrower core of 0.005 millimetres. This has largely solved the problem of dispersion (compare B_1 and B_2). Furthermore, capacity and speed are higher than the multi-mode fibre, even though the fibre is much thinner.

Optical fibre has the best properties in the area with wavelength of 800 to1600 nm, the area just beyond the visible spectrum. Two types of light sources can be used to transform an electromagnetic signal into light pulses within the reach of 800 to 1600 nm: light emitting diodes (LED's) and laser diodes. The latter type is much more expensive, but also faster and more powerful. At the receivers' end of an optical

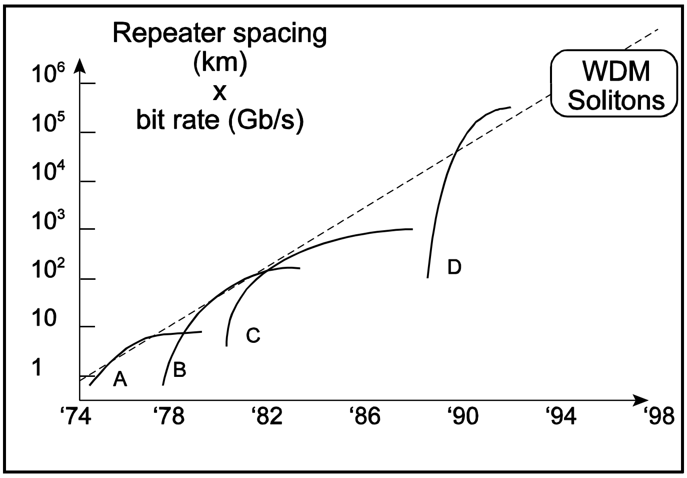

Figure 24 *The growth of the transmission capacity of optical glass fibre*
Curve A: multimode fibre at 0.8 mm wavelength
Curve B: single-mode fibre at 1.3 mm wavelength
Curve C: Multimode fibre and single frequency laser
Curve D: Optical amplification (Erbium Doped Optical Fibre: EDFA)
Source: van Etten, 1999

fibre transmission channel a photodiode converts the light pulses back into electromagnetic waves. Optical fibres have excellent properties for a range of modulation techniques.
It is relatively easy to transmit several wavelengths (colours) on one fibre at the same time. This is a specific variant of modulation which is called wave division multiplexing (WDM). The technology of using two colours, also allows for bi-directional traffic at the same time.

The technologies of enhancing the capacity of optical fibre by using different colours are now developed up to the level that one single fibre, can transmit 2.5 Gbit/s using just one colour and 200 Gbit/s when 80 colours are used at the same time. That is one and a half million telephone calls at the same time. This technology is called dense wave division multiplexing (DWDM).

The capacity of optical fibres is enormous, while problems of attenuation and other disturbances are low. It is no problem to bridge distances longer than 100 kilometres, without any kind of amplification in between. Developments in optical fibre technology are very fast, and more or less comparable to Moore's law in the computer industry. The capacity of optical fibre has doubled every year; a doubling that is going on for 25 years now (van Etten, 1999).
The advantages of an optical fibre are, next to the technological specification, its reliability, its insensitivity to electromagnetic disturbances and its safety, because optical signals are very difficult to (illegally) tap.

Unguided Transmission Media

Unguided transmission media are basically radio-waves propagated through the air. As mentioned before, this is a rather inefficient way of transmitting signals, because radio waves are soon attenuated (as is shown in the figure under A). However, there are several ways to solve this problem. One is to collimate the signal and another is to increase the signal's frequency.

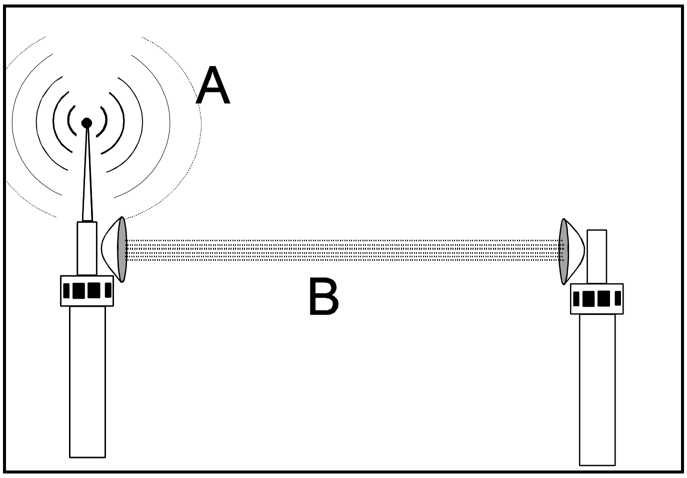

Figure 25 *Radio beam link transmission*

A radio-beam link is a bundle of high frequence radio waves travelling in a straight line. A directional beam aerial (a parabolic dish), mounted high upon a radio tower, is directed towards a beam aerial on another tower (as is shown in the figure under B). This technology demands radio-towers or other high buildings to avoid the curvature of the earth-surface and other obstacles. In practice these towers are 50 to 100 metres high and cover a distance between 30 and 50 kilometres. This technology is especially used for trunk transmission in telephony and for the distribution of radio and television programmes.

Radio beams technology is an open technology which demands strict management of frequencies, to avoid that different radio-beams interfere with each other. Radio-beams have specific set of problems. They are susceptible to small interferences, especially fading and atmospheric disturbances. Even rain or atmospheric disturbances may influence the quality of the signal.

A big advantage of radio-beam links is that they can be set up very quick, which makes this technology especially suited for temporary connections, for instance for (sport) events. They are also suited to bridge distance in rough and non-accessible grounds.

A satellite is basically a radio-beam link in space. Each telecommunication satellite contains a receiver, a frequency transformer and a transmitter, a combination of functions usually addressed in one word: a transponder. One satellite may has several transponders, aimed at several points on earth and/or several other satellites.

There are three types of satellites: Geo-stationary satellites (GEO's), Medium Earth Orbit satellites (MEO's) and Low Earth Orbit satellites (LEO's).

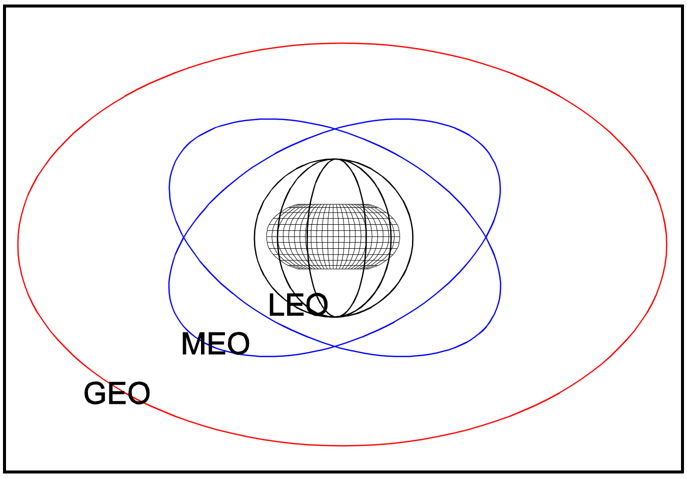

Figure 26 *Schematic representation of the orbits of three types of satellites*

GEO satellites have an orbit of 24 hours, the same as the rotation of the earth and that is why the GEO satellites have a stationary position in relation to the earth surface. These satellites are very powerful, have a large capacity and can be used for a range of tasks. Its large distance to the earth (35,767 km above the equator) however, has the dis-advantage that large aerials are needed and trans-mission has a delay of 260 milliseconds. Three GEO satellites can basically cover the whole earth surface, except for the North and South Pole.

MEO satellites have a much smaller distance to the earth (± 12,000 kilometre). These satellites, however, do not hold a stationary position, but have an orbit of ± 6 hours. They also have a time delay, however, much smaller than of GEO's (± 100 milliseconds). To cover the whole earth-surface, ± 12 satellites are needed.

LEO satellites have a position closest to the earth (between 500 and 2000 kilometres). The simpler types are used for relatively easy tasks, such as data communication. The more sophisticated types are used for telephony and the Global Positioning System (GPS), which is used for navigation. 48 to 66 satellites are needed to cover the whole surface of the earth (the number depends on the altitude of the satellite).

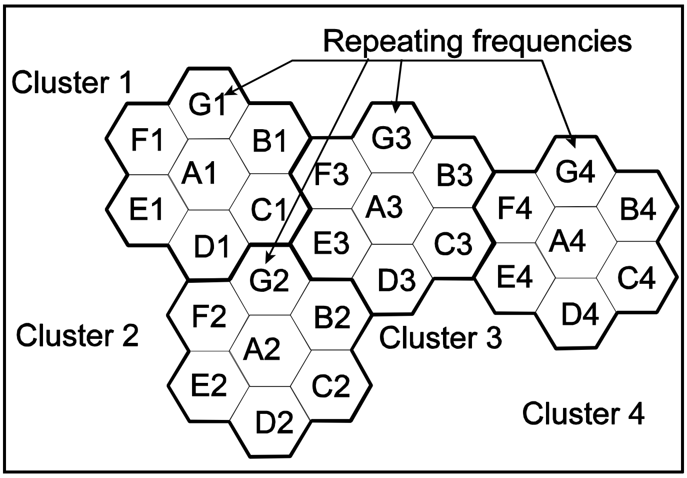

Figure 27 *Clusters and cells in mobile communication*

A mixture of guided and unguided transmission is to be found in mobile networks. Mobile radio communication is applied in radio-systems with moving end stations. This demands a specific setup, because mobile communication is limited to frequencies between 30 MHz and 2 GHz. A lower frequency is not applicable, because the user sets and the base stations are limited to a certain reach. Frequencies higher than 2 Ghz cause fading in moving objects and hence cannot be applied. The mobile telecommunication system has two major elements: a cellular network of base-stations and end-user stations (the 'handy'). Each region (a cluster) is covered by a number of cells. Neighbouring cells within each cluster always have a different frequency to avoid interference between cells. The reach of a cell is however, limited. This gives the advantage that a frequency can be repeated in another cluster. This is called frequency re-use (see cells G_{1-4}) in the graph opposite). This makes it possible to offer regional or even national coverage, just using a limited number of frequencies.

The size of cells is very important. The smaller the cells, the larger its capacity. Small cells are commonly used in urban areas with intensive traffic, while large cells are more applicable in thinly populated rural areas. A disadvantage of small cells is that the chance of interference is larger. Also, the cost of the infrastructure is considerably larger. The design of a cellular network is always a balance between capacity, quality and costs.

The diameter of a cell in a mobile telephone network can vary between several hundred metres and some dozens of kilometres. Shape and size of cells can vary considerably and the mobile network does not have the orderly shape as it is presented in the graph.

Some base stations are built in the centre of a cell and are called omni-directional aerials. More common however, is to build base stations on the crossing of three cells. In that case three aerials are used, each with an angle of 120^0, and each with a different frequency.

A mobile subscriber travelling from one cell into another is switched automatically to the next cell; this procedure is usually called a handover. It may, however, be the case that all capacity of that next cell is in use. In that case the first cell is not able to hand over and the connection will only stay in the air for as long as the distance between the mobile station and the base station is not too big.

3.4.6 Switching

Switching is the technology to handle a message in a network from one end-user to another. There are basically two systems for switching signals: circuit-switching and packet-switching. To understand the difference between these technologies, we have to look at the origins of each technology, namely telephony and telegraphy.

Circuit switching has its origins in telephony. In the first years of telephony, an operator was needed to establish an exclusive galvanic connection between two individual subscribers. After the conversation was over, the line was disconnected and the circuits between switching nodes were opened for new connections. This basic principle has not changed, even though operators have been replaced by automatic switch-boards and the physical circuits between the switching nodes have been replaced by electronic circuits.

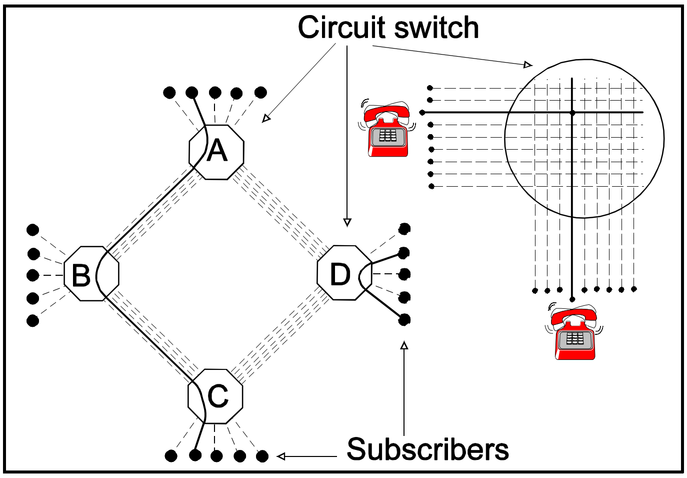

Figure 28 *Circuit switching*

Today's telephony networks (PSTN, ISDN, GSM) and the telex network are examples of circuit switched networks. Prior to a conversation, a galvanic connection is set up between two subscribers of the telephone network. This connection is an exclusive line between the two subscribers. This is a guaranteed exclusive connection that cannot be used by any other subscribers. A connection can only be established if the line is free. If not, the caller will hear a tone that the line is engaged. A second characteristic is that there is a minor but stable delay in the connection. In practice telephony is a real time service.

Packet switching has its origins in telegraphy. A telegram usually had to cross several telegraph stations before it reached its place of destination. Usual procedure was that the telegram was transmitted to the nearest telegraph-station in line. There it arrived as punches in a stream of paper-tape. The operator could read the address in the punched pattern and he made the connection with the next station in line and inserted the punched paper-tape into a reader. At the station of destination the punched tape was translated into a typed message and finally delivered at the receiver. However, in this procedure it could be that the operator was busy handling another telegram first, or that the postman was not immediately free to deliver the telegram. In that case the telegram was stored and delivered at a later moment. This type of switching is called store-and-forward switching and we find this sequence basically unchanged in data transmission.

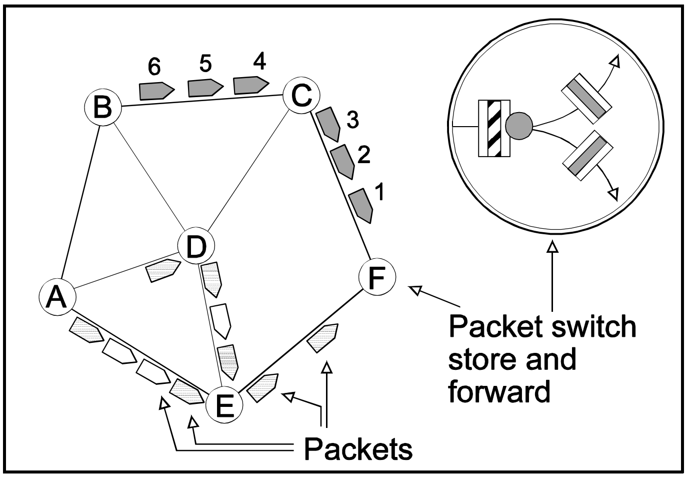

Figure 29 *Packet switching*

The practical difference between circuit switching and packet switching is the variation in time-delay between sending and receiving. This is not a problem as long as the message contains just data. However, time-delay in voice communication is a serious problem, because it will influence the fluency of the conversation. To make the most efficient use of the network in packet-switched networks, all information is cut into separate packets of equal size and a label is attached to each packet. The label contains the addresses of the source (sender) and the destination (receiver). The label also contains information that is needed for a proper delivery through the network. On its way through the network the packet has to cross one or more nodes, where it is stored in an input-buffer (store). Depending on the information on the label the packet is placed in an output-buffer, where it waits until the network is able to send the packet (forward). The nodes in this network are called routers, because they guide the packet through the network (routing). There are basically two different technologies in packet-switching: as a datagram or through virtual circuits.

A network using data-grammes considers each packet as a single unit. In the graph this is represented by the striped packets. Every router in the network decides for each single packet which route is best suited. As a result the packets of one single file may follow different routes to their destination and arrive in a different sequence than they had been sent, which might mix up the original message (in the graph route A-D-E-F for some packets and A-E-F for others). Another problem is that, due to network errors or due to congestion in the buffers, packets are only partly transmitted or do not arrive at all. Most of the datagram-networks do not check if the packets that were offered for transmission in fact have arrived at the place of destination. They also do not give error-warnings.

	Telephone world	**Data world**	**Radio/TV world**
Requirements	Telephone (dialogue)	Internet, PC (messaging, retrieval, transaction)	CaTV system, TV sets & radio's (distribution)
Intelligence			
Two-way communication			
Switching, addressing			
Billing, security			
Real time			
Broadband			

Table 18 *Convergence in three telecommunication worlds*
Source: van Etten, 1999

A network that is designed for virtual circuits is based on a different technology. Prior to the actual transmission of the packets a datagram is sent through the network. This datagram contains all the address data on its label and also a short serial number. The datagram is routed through the network as outlined in the above. Every router that is passed by the datagram notes several data of the datagram in a

table, namely the entrance-route, the serial number, and the exit route. When the datagram has reached its place of destination, a similar datagram is sent back, so that a route from source to destination and an alternative route from destination back to the source (for monitoring the transmission) is established. In this way a virtual circuit is created and the packets are now easily guided along that circuit to their destination (the grey packets in the graph). Packets can easily pass the routers, because the routing-decisions have already been taken and the router just has to check the short serial numbers. All packets follow the same route and arrive in the same order as they have been sent. Also, error control is provided. Virtual circuits make economically use of the transmission capacity of a network.
The characteristics of virtual circuits resemble circuit- switching technology, but there are still some differences. The circuit is not exclusive and there is no fixed capacity reserved for the circuit.

The principles that are outlined in the above may seem to differ a lot and in fact they do. However, in practice the irregular time-delay between sending and receiving, that used to be a main characteristic in packet-switching is now decreasing very fast. The performance of a packet-switched network is approaching the fixed time-delay that until now has characterised the telephone-network. Voice over IP, which uses data networks for voice communication, is still in its experimental stage, but it is believed to be the dominant technology for the future.

In fact, there is a process of convergence in which telephony, data transmission and CaTV networks, gradually develop the same characteristics. Van Etten (1999) found that, historically, three different worlds in telecommunications have evolved.

- the telephone world, with its high degree of standardisation, reliability, billing and security, and real time service;
- the data world, which is less standardised, lacks real time service and for the greater part uses the public switched telephone network (PSTN) as a carrier service;
- the CaTV world, which is a pure distributive, stand alone network, with broadband facilities, but lacks the switching and billing facilities.

It is expected that for future applications, such as multimedia communication, where different kinds of two-way services (data, text, graphics, audio and video) are offered in a single, integrated service, a vast amount of real time transmission is required. Moreover, switching, billing and security should be provided as universal network services. The future telecommunication network has to combine all the features of the various existing networks into a new, worldwide broadband integrated service digital network (BISDN). The key-technologies of this network are: fibre transmission, (optical) switching, multiplexing and routing, combined with high speed electronic processing in the nodes and terminals. (Van Etten, 1999). Some of the features, which are regarded to be forerunners in this process of convergence are already available, however, still on an experimental base. A wider application may take several years. IP telephony is in its experimental stage; pay TV and telephony over CaTV are already available.

Paced by the optical fibre as a high capacity, high speed transmission medium, fast developments in (optical) switching and the rapid development of information technology, the telecommunication market has changed drastically and these changes are still going on. Van Etten listed the major characteristics of the past and future telecommunication system:

Past		***Future***
• high performance, low volume	➜	low cost, large volume
• slow change	➜	constant change
• centrally switched	➜	distributed switched, user control
• few large network providers	➜	many small, agile network providers
• regulated market	➜	competitive market

•	long range research and planning	➜	long term = 3 years
•	standardised design	➜	standardised interfaces, many proprietary solutions

Table 19 Some important characteristics of the past and future telecommunication system
Source: van Etten

3.4.7 The telecommunication network

Any telecommunication network can be understood as a coherent system of transmission media, connection points and switching nodes to enable individual subscribers to communicate over distance (point-to-point transmission) or to send a signal from one sender to multiple receivers (point-to-multipoint transmission). The telecommunication network was initially built to provide telegraph and telephone services, but gradually, especially since the advent of computer-technology and digitalisation of the telecommunication signals, a range of new services has been added to the classical telecommunication network.

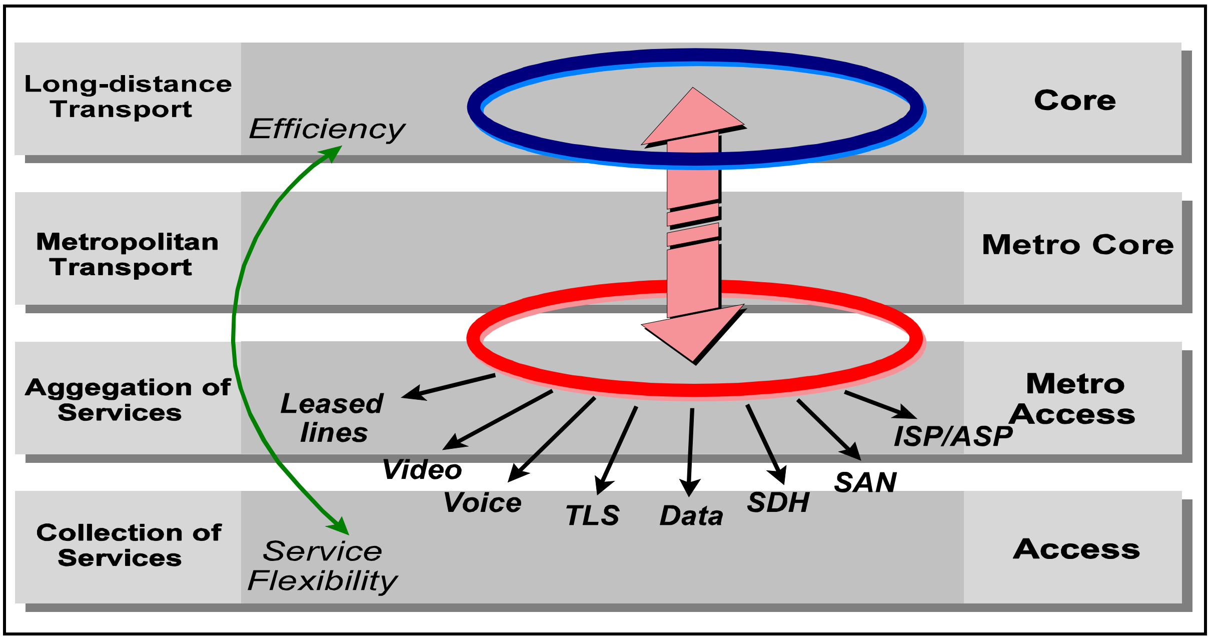

Figure 30 *Metropolitan Area Network Overview and Layering*
APS: Application Service Provider
SAN: Storage Area Network
TLS: Transparent LAN Services
ISP: Internet Service Provider
SDH: Synchronous Digital Hierarchy
Source: Daans/ Alcatel Telecommunications Review, 2002

The figure opposite, which is just a model for a telecommunication network, shows the hierarchical layering of a telecommunication network, with each layer performing a specific function. Depending on the scale or complexity of a particular network, some layers might be divided into still more sub-layers. As regards network deployment, there are many differences between the state of advancement of different networks according to the operator's history and business focus (Daans, 2002).

We will briefly discuss some relevant network technologies, starting with the hierarchical structure of the classical, voice oriented, telecommunication networks. We will outline the general setup of such a network and explain how the individual is connected to the system in the local loop. With this we have a general notion of the telecommunication network and this makes it easier to comprehend that different functions are provided by the same physical network. We will also briefly discuss the setup of the mobile telecommunication network with its cellular setup and the CaTV network which used to be a uni-directional telecommunication network.

Hierarchical network

The telephone network has a hierarchical structure and is composed of four layers[3]. The lower layer, closest to the individual subscribers, is the local network. The three top layers form the trunk or transport network and are not connected to individual subscribers. The trunk network is the highway between the switching nodes. Above the top layer there is in fact another layer that connects the national network to the international networks.

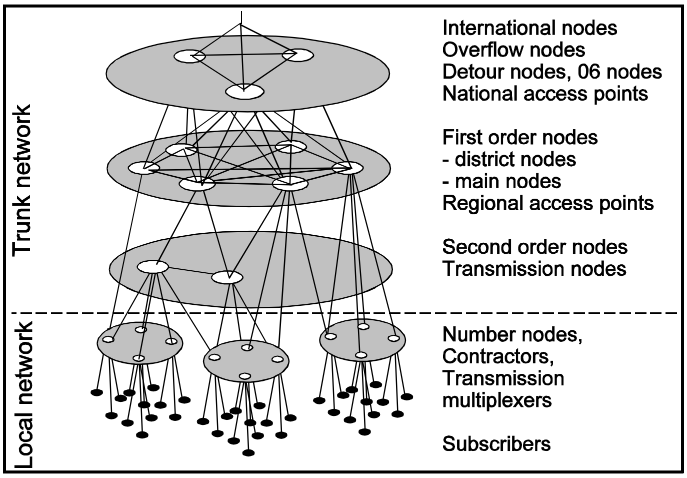

Figure 31 *Dutch KPN's network structure*

The trunk network connects local networks, international networks and other networks like mobile networks or radio-telephone (paging) networks. The local networks are connected to the second order nodes in a star-shaped mode, which are also star-shaped-like, connected to the first order nodes. All first order nodes are mesh-like connected to each other.

There is a tendency to replace the lower layer in the trunk-network (the second order switching nodes) by transmission-shunt nodes -as we find them in the local networks- or to integrate its function into the first order switching nodes. As a result, the lower layer in the trunk network is dissolving.

All trunk telephony traffic is handled in the first order switching nodes. However, in case of congestion, traffic is detoured over the switching-nodes in the top layer. The top layer of the trunk network is also connected to networks for special functions and the international switching nodes.

Connecting the subscriber

The local network has all the elements needed to connect an individual subscriber to the network.

---

[3] Example taken from Dutch KPN. Other countries have more or less similar structures

Each number node has two elements: the switching unit and the main distribution frame (MDF).
The switching unit is an electronic device that connects and manipulates in- and out coming traffic. Each individual subscriber is connected to a line-card, which is an electronic card that is placed in the line-block, which has several joint features, as for instance switching circuits. The main distribution frame divides the connections between the switching unit and the subscribers.
Thick cables, often with several hundred twisted pairs are connected to the first distribution units. There the cable is separated into several smaller cables, which are connected to second distribution units, where the cables are separated again into smaller cables. Finally the cable, which then has two pairs of twisted copper, is connected to the private subscriber. One pair is connected to the network, the other pair is a loose pair, which is reserved for a second line. The network ends in the subscriber's premises in the connection point for end-user equipment. The connection between the number node and the subscriber is of the analogue type. The analogue signal is only converted into a digital signal in the number node. That is the case, unless an ISDN connection is used, because ISDN equipment transforms the signal into a digital signal already at the subscriber's premises.

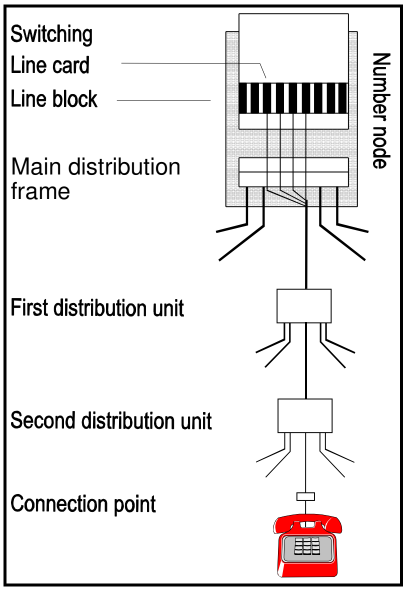

Figure 32 *Elements of the local loop*

Local loop-technologies

The infrastructure from the number-nodes to the subscriber's premises is called the local loop and in fact there have hardly been any recent developments in the hardware that connects the individual subscriber to the network. The same double set of twisted copper pair is to be found unchanged from the 1960's on. Yet, the need for capacity has undergone an enormous growth in recent years, so that the local loop is increasingly becoming a bottle-neck in transmission, especially for Internet and broadband services. There are several ways to solve the problem. It is obvious that the best way to solve the problem is the replacement of all copper wires by optical fibre. Until now this has been a too expensive solution, but there is a discussion in several countries to connect all private subscribers to the optical fibre network, starting with new housing projects. Consequently network-operators offer technological solutions which use of the existing cable infrastructure. Alternative technologies for the local loop bypass the existing network infrastructure within the "last mile" providing high transmission capacity through wireless solutions.

Today's most established solution for high capacity transmission within the local loop is the Digital Subscriber Line (DSL). There are different DSL systems in place which are based either on traditional copper connections or on a direct satellite connection. The most common form of DSL is the Asynchronous Digital Subscriber Line (ADSL) which offers end-users and bandwidth of about 800 kbit/s for data retrieval and about 384 kbit/s for data sending. Before a customer can subscribe to ADSL via fixed line networks he/she has to install a modem, known as the ADSL termination unit, at his/her premise. The network operator allocates the respective transmission capacity by connecting the end-user to his high capacity backbone network which is in most cases a packet-switched ATM network. The allocation of a defined bandwidth to individual customers requires the installation of an ATM Access Multiplexer (ASAM) at the central office. Because of the required hardware at both sides of the local network, ADSL via copper cables is a service which can only be provided economically in metropolitan areas. For regions with a low population density an alternative exists with ADSL via direct satellite connection which offers a downstream bandwidth of 4 to 8 Mbit/s. However, a customer who decides in favour of ADSL via satellite still needs a fixed-line connection with a traditional Internet service provider. Commercial systems which realize both the up- and downstream directly over satellites are not available yet, because of the enormous costs of about € 10.000 for satellite dishes which can be used for sending and receiving. In contrast to ADSL, a Synchronous Digital Subscriber Line (SDSL) offers a bandwidth of up to 2.3 Mbit/s. However, SDSL can be offered only via the fixed-line local network.

The dominant technology for the Wireless Local Loop (WLL) is directional radio which makes use of microwaves in order to send and receive data within the Gigahertz area of the frequency spectrum. With directional radio, end-users have a bandwidth of about 34 Mbit/s at their disposal. Directional radio requires the installation of a parabolic antenna on the user’s premises. Because of the costs for the wireless network infrastructure, directional radio is suited very well for metropolitan areas. Customers who use directional radio will do so especially because of their need for high capacity data transmission.

Powerline is the most recent technical development for the local loop. In contrast to other last mile technologies, Powerline uses in-house electricity cables for voice and data communications with a maximum bi-directional bandwidth of 1 Mbit/s. The great advantage of Powerline is its availability in virtually every household. However, even with powerline, users cannot plug in their terminals in every socket; they will only be able to access the powerline network at the central fuse-box.

Integrated networks

Different networks have existed for telephone, telegraph and telex services until digital switching and transmission technology were introduced into the public telecommunications network. Digitalisation made possible the establishment of the ISDN network, which integrates the transmission of voice, data, text and images. ISDN has considerable advantages for network operators as well as their customers. For network operators, ISDN networks are easier to manage, and more cost-effective. With the availability of a much broader range of services, network operators are able to differentiate from competitors by offering special services. Moreover, three major principles in switching can be combined with ISDN: circuit switching, packet switching, and message switching.

In view of the customers who are connected to ISDN, the main advantages of ISDN over the former analogue network are a higher capacity for data transmission, the availability of various new services especially for voice telephony, and the opportunity to connect a variety of specialized or multi-functional terminals to the user’s premise. Subscribers to the Integrated Services Digital Network have two channels at their disposal with a capacity of 64 Kbit/s each. If they use ISDN for data transmission, the capacity of both channels can be combined to a total bandwidth of 128 Kbit/s. In view of voice telephony, various new services such as transfer call, abbreviated dialling, conference call, and detailed billing are available.

Mobile communication

Mobile communication systems which are based on the transmission of signals over radio waves were first introduced in the first half of the 20th century as specific communication systems for police vehicles (1920) or journalists (1946). As for public use, mobile communication systems became available in the 1950's and were based on analogue technology. Consequently, the number of subscribers remained low and mobility was limited since a person who called up a mobile phone had to be aware of the location of the person who owned the mobile device. Cellular systems, still based on analogue technology, emerged in the 1980's and allowed for higher mobility since the users of a mobile handset could be reached as long as they were located within any cell of the network.

However, the breakthrough for mass usage of mobile communications came when digital technology was introduced as the second generation of mobile communications systems (GSM/DCS). The elements of a GSM Network are outlined in the graph opposite.

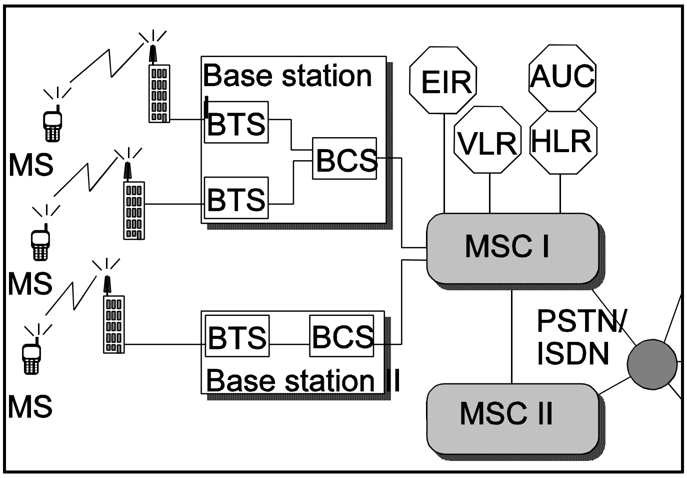

Figure 33 *Structure of a GSM network*

The mobile handset of an individual subscriber or the car-telephone is useless, unless it has a Subscriber Identity Module, a so-called SIM-card, which is a chip-card with all the necessary details of the subscriber. Only the combination of handset and card form a mobile station (MS). Mobile stations communicate with base-stations (BS). Each base station has a base transceiver station (BTS) which is the send- and receive equipment and the aerial. It also has a base station controller (BCS) which is in fact a small node that manages free radio-channels and the handover process (switching from one cell to another).

The mobile switching centre (MSC) is a bigger node that connects GSM users. Each MCS is connected to a number of base stations, to other mobile switching centres and to the fixed (public) network (PSTN or ISDN). An MSC has several registers with important data, such as:

- the home location register (HLR), which contains all the details of the networks own subscribers, such as subscription data, features and services that are accessible for individual subscribers and also data on blocked services. The HLR also has an authentication centre, that manages authentication and encryption;
- the visitors location register (VLR), which contains data on subscribers who are in the area. Each mobile station, that is switched on by its owner, is traced by the system. These first two registers are characteristic for a mobile network and enable roaming nationally as well as internationally;
- the equipment identity register (EIR), which holds the identity of mobile stations and is a useful tool, for instance, in tracking stolen handsets.

These features basically provide safety for the subscribers. They are designed to avoid abuse of equipment, but also to protect the subscriber’s privacy. If a subscriber requires access to the mobile network, the network first checks if the subscriber’s identity and the secret key, which is provided by the network operator. Also to safeguard privacy, the identification numbers are only temporarily valid and changed often, which makes it almost impossible to trace individual GSM users. Data and voice are encrypted during transmission, so that it is fairly impossible to tap GSM connections.

GSM is adopted by the European countries and is the leading standard in mobile communication. Other states, like the United States for instance, use different standards (CDMA), which is not compatible with GSM technology. The ITU took the initiative to develop a set of worldwide standards. This initiative called International Mobile Telecommunications for the year 2000 (IMT2000), was meant to develop a new set of standards for third generation mobile equipment. However, the parties involved did not agree upon the technology and IMT2000 is now presented as a family of related systems that allow worldwide roaming.

The Universal Mobile Telecommunications Systems (UMTS) is the European member of this

family. It was originally designed as a system that aimed to replace all mobile systems (analogue and digital mobile systems, cordless telephones (DECT)), but the tremendous growth and success of GSM technology shifted the attention towards new mobile services like the Internet and mobile multimedia. UMTS will provide a much higher capacity than GSM. 144 Kbit/s in fast moving objects (cars and trains), 384 Kbit/s in slow moving objects (walking) and 2Mbit/s for fixed units.
On the way from GSM towards UMTS three steps already provide technological standards with higher capacity: High Speed Circuit Switched Data (HSCSD) with a maximum of 57,600 bit/s, General Packet Radio Service (GPRS) allowing for transmission at 115 Kbit/s and Enhanced Data Rate for GSM Evolution (EDGE), which can transmit at 384 Kbit/s.

CaTV networks

CaTV networks were basically designed for uni-directional broadcasting purposes, also called point to multipoint transmission. Its basic architecture consisted of a system of aerials, cables and amplifiers to transmit radio- and television programmes. The setup of the network largely resembles the structure of a telephone network. The cables, initially used in the CaTV network were coax cables. The amplifiers needed to keep the analogue signal stable over distance were of the unidirectional type, which limited the network to broadcasting purposes. However, the replacement of coax cables in the trunk by optical fibres provided the opportunity to rebuild the network for bi-directional traffic, enabling new services, like the Internet and telephony.

3.4.8 End user equipment

The only telephones in most countries available until the 1970's were uniform telephone-sets, built to national standards. The US had the well known ‘vanilla’ type of rotary telephone, Germany had the off-white model and the Netherlands had a grey-white model. Although these telephones were not interchangeable among countries, they basically had the same elements: a rotary dial and a handset, containing a (carbon) microphone and a speaker. Innovations in switching technology, especially the change from electro-mechanical to semi-electronic switches enabled a new dialling technology. From that moment on telephones were equipped with a tone dialling device; push buttons instead of a rotary dial.

> For remote areas, still using the (then already outdated) electro-mechanical switching technology, a special telephone set was designed for customers who preferred to use the modern push button technology. A chip was built in the telephone-set and served as a small kind of register. The number was first stored in the telephone’s register-chip and then transmitted to the switching node. This model did not have the advantages of its modern equivalent, because these new models were much faster. The ‘would-be-modern’ telephones could only operate at the speed of the old-fashioned rotary dial.

Box 8 *‘Cheating’ with modern technology*

As technology made progress more and more features were offered to end-users. In the first stages of development these features were built in, in the infrastructure, like time- and weather report or weak-up calls. Later more and more features were built in the telephone handset, like for instance a number register, a consultation button, redial button and number display.

The most important technological change was, however, the miniaturisation of electronic devices. The carbon microphone was replaced by a capacitor-microphone and the hearing device was made a lot smaller. New designs and an exploding number of features have changed the telephone-set from a utility liable to the rules of technology into an object liable to the laws of lifestyle and fashion.

Telephones can be attached directly to the termination point of the public network; the telephone at home is plugging into its connection point. That is also the case for mobile equipment, even though there is no visible connection between the network and the terminal. However, there is a constant connection, using radio-waves as the connecting medium. The same holds for satellite telephones that are directly connected to communication satellites.

Wireless telephony is a marginal case. The terminal (hand set) is not directly connected to the network, but to a base-station, which in turn is connected to the fixed network. These mobile devices were introduced while using analogue technology. Nowadays most of the devices are based upon Digital Enhanced Cordless Telecommunications (DECT) standards. All these systems are known as direct systems. Indirect systems, like for instance IP telephones, require a personal computer and a modem as mediating devices. Internet telephony does not use the telephone network, but the data network. This has some far reaching consequences, some of which are considered to be an advantage, others a disadvantage. The main advantage of 'voice over IP' -which is the common name for telephony over the Internet- is that it is much cheaper, especially in international telephony. The subscriber just pays for his connection to his local service provider, which is only a fraction of international fees. This makes voice over IP especially attractive for business applications. A disadvantage, however, is inherent to the fact that the data-network is used for data transmission, and this type of system has an irregular time delay. No matter how small the time-delay, it can obstruct the fluency of a conversation considerably. A second consequence is that bits and pieces might get lost in transmission because packets might follow different routes and arrive at the place of destination in a different sequence then they were sent. Again, this might influence the fluency, and even audibility of a conversation. However, technology is work under progress and it is expected that these disadvantages will be solved in the very near future.

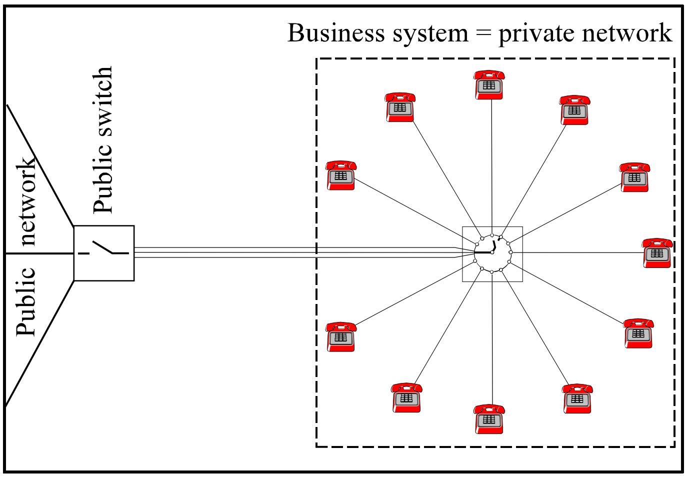

Figure 34 *PXB or PABX (Private (Automated) Branch Exchange)*

A special case of indirect telephony system is to be found in business systems. A business system is basically a private network that is connected to the public network. People within the private network can communicate with each other, without being charged by the operator. However, for outside calls to subscribers in the public network, the company is charged. That also makes the biggest difference between public switching equipment and private or business switching equipment. The former has extensive accounting and billing features, while the latter lacks those features. Business systems on the other hand have often more sophisticated features than those which are provided to the public network. Usually a business system is addressed as a Private Branch Exchange (PBX). A PBX has an operator to handle incoming calls, but its automated version, the Private Automated Branch Exchange (PABX), does no longer require the mediation of an operator.

Small PBX systems (up to ± 70 users) are also called Key Systems. Their functionality used to be smaller than the larger PBX systems. However, modern machines provide virtually the same functionality. Key systems and P(A)BX systems are installed at the companies premises. This in contrary to Centrex system that offer the same functionality, but is installed as a part of the public network.

Business systems are often containers with old and new equipment. The heart of the system is the (analogue or digital) switch. The network and the end-user equipment can be of different make and different age. The functionality of the system is not so much determined by its hardware, but rather by the software. This allows for flexible solutions. An update of the operation system is easier to implement than a full replacement of hardware.

Technological developments in the public telephony sector have their equivalents in business systems. Mobile cellular systems and Voice over IP are under development in business-systems. Further integration is to be found in the technological merger between GSM technology and mobile business systems technology. The same terminals can be used at the company's premise, for which the company is not charged, as well as outside the premise, as a normal GSM telephone, for which the company is charged by the service provider.

Several devices can be connected to the public network for special purposes. Modems connect computers to the network. Modems convert the digital signals received from computers into analogue signals to be transmitted over analogue lines. At the other end the receiver's modem converts the analogue signal into a digital signal, calling demodulation. A special type of modem is the PCMCIA-card that is used for lap-top computers. PCMCIA stands for Personal Computer Memory Card International Association. They are manufactured in a range of speeds, including 56 Kbit/s, which is a commonly used speed in modems.

Fax machines have an internal modem that transmit on 9600 bps. Fax machines are regarded as a merger, which combines between the functionality of post and telephony. The format of a message is a letter, transmitted through the telephone network.

Paging devices are mobile receivers according to the ERMES standards (European Radio Messaging System). Paging, however, is basically a uni-directional telecommunication service, which is one reason to devote no further attention to this system. Another reason is that paging is overruled by GSM technology that offers far more functionality at a reasonable price.

3.5 Biotechnology

Biotechnology has been at the centre of the public debate, especially during the nineteen nineties, during which the public strongly opposed to genetically modified organisms in food, agricultural products and animals. Under the beggar's flag the term 'Frankenstein food' was introduced, thus polarising the public debate.

The intensity of the debate easily leads to the impression that biotechnology is a novel technology, 'invented' at the end of the twentieth century. The shower of public attention is, however, misleading. The principles of biotechnology have been known from ancient times; in fact, biotechnology is older than written history. Malting and fermentations were already practised in 4000 BC in Mesopotamia and the ancient Egyptians were familiar with the use of yeast, to set dough to rise. Bio-technological principles have also been used in winemaking and the brewing of beer. For centuries people have known how to use fermentation processes, which change sugar into alcohol. However, they applied the technology, but did not understand the underlying scientific principles. Knowledge of these processes was mostly tacit, passed down through the ages from father to son, from mother to daughter. Variations in skills were subject to trial and experiment and usually based on local traditions.

The early codification of the underlying scientific principles has only taken place in the nineteenth century. Scientists came to understand the function of yeast and started to diversify separate strains of yeast-cultures. Yeast for the production of bread, for instance, was taken from different cultures than yeast to be used in the production of beer. With the increase of knowledge about the behaviour of micro-organisms and moulds one could increasingly use transformation processes for specific, well-defined targets in food-processing, thus increasing efficiency and decreasing costs.

Next to yeast and several other mild bacteria, also several enzymes were used to alter the properties of foodstuffs. Enzymes are used as a catalytic agent for chemical processes in living organisms at low temperatures and neutral pH-value (den Hartog, 1988). Enzymes, usually proteins, have a specific function and regulate reactions in every cell which makes them a necessity for virtually all life-processes, especially in the metabolism. Enzymes, for instance, are used in the production of cheese (rennet), and here again, cheese-makers had initially only limited abilities to control the process and to predict the final quality of their products. But enzymes were not only used in the production of dairy-foodstuffs. Potato-starch was already in the nineteenth century used as a basic compound for the transformation into several derivatives like sago (thickener), glucose and dextrose. Especially since world-war II, the potato has been explored, fractionated and analysed as a 'chemical goldmine' (Dendermonde, 1979). Enzymes are widely used in the fruit and vegetable industry. Fruit-presses are rather efficient in fruits like grapes and oranges, but have much more difficulty with soft fruits like cherries, berries, apples and bananas. Pressing these fruits results in thick ooze, because the molecules in the cell wall do not release the juice so easily. By adding purified fungus extract to the ooze, the enzymes can open the cell wall and release the juice. This process has improved viscosity as well as colour of these juices (van Otterloo, 2000, pp. 302-3).

> The discovery of Penicillin is an interesting case. Its discovery was not so much the result of thorough scientific research, intended to find an antibiotic, it was rather an unintended side effect of Fleming's research on influenza. However, when a mould by accident had contaminated one of his culture plates and destroyed the bacteria, he understood the potential of this discovery and developed the results into penicillin. Thus, trial and error and sheer luck stood at the basis of this important discovery.

Box 9 *The role of incident and accident in innovations*

Next to biotech applications in agriculture and food-production, these bio-technological processes also widely used in drug production, especially in the production of antibiotics. Penicillin for instance is grown as a fungus and subsequently 'harvested' for the production of drugs. Fungus and moulds contain the active substance in a range of antibiotics. This discovery has lead to an explosive growth in medicine-development and to a deeper understanding of the underlying natural processes.

The breeding of life-stock and crops has been a challenge for ancient farmers. They have constantly tried to improve the quality of cattle as well as crops through the combination of the most promising species. Dutch farmers have been very successful in their attempts. Already in early-modern times there were distinctly different production systems in Europe with marked differences in productivity. This was the case in arable farming as well as in cattle breeding. The yield of wheat in the Netherlands was among the highest in Europe (Slichter van Bath, 1963). Foreigners, travelling through the Northern Netherlands in the seventeenth century, were amazed by the productivity of the life-stock. An annual milk-yield of 2000 litre was not uncommon for the Netherlands, while this was often below 800 litre in other European countries (Bieleman, 1992).

Progress in the selective breeding of plants was especially based on the work of Georg Mendel (1822-1884). In experiments with the cross-breeding of peas he found that the characteristics of the parents were divided among their offspring, according to a certain regular pattern. His results were confirmed by independent research and were applied as the axioms of modern hereditary theory. William Bateson found that the hereditary principles in plants were also valid for animals, and he introduced the term 'genetics'. As a result of breeding, cross-breeding and hybridisation, farmers managed to grow the sugar-beet as we know it today, from a tine root that originally grew in the dunes. A good eye for the right combination was the necessary asset for a farmer who wanted to improve quality of life stock and crops.

Knowledge of biological processes and the application of knowledge form the link in the technologies discussed in the above. 'Biotechnology' as a scientific term to cover a range of technologies was only used for the first time at the beginning of the twentieth century. It gave common knowledge as it was developed in so many ages its science base. Its reach has been gradually extended ever since. A giant leap forwards was the discovery of the DNA-structure in 1953 by Crick and Watson. Their work helped to understand the hereditary properties of species, whether in small organisms, like in yeast, bacteria, en enzymes, as in larger and more complex organisms. Knowledge of the gene-structure held the promise of new approaches in biotechnology. Instead of the trial and error approach in traditional biotechnology with its uncertain outcomes, this knowledge provided the basic ingredients to target specific and well, pre-defined outcomes. In 1973 Stanley Cohen, Annie Chang and Herbert Boyer of Stanford University and the University of California undertook the first recombinant DNA experiments. In 1982 the Eli Lilly company introduced insulin produced by a genetically modified strain of bacteria. As a result, vastly greater quantities of insulin became available at an economic price and -in contrast to the old product- without any allergic side effects. In the late 1980's and early 1990's genetically modified, so called transgenic plants and animals followed. The tomato Flavr Savr and the Dutch bull Herman were the frontrunners in this development (Tramper, 2001, pp. 146-9).

These developments, starting with recombinant-DNA technology, are usually labelled as modern biotechnology, but both classical as modern biotechnology stem from the same definition: 'the integration of natural science and engineering in order to achieve the application of organisms, cells, parts thereof and molecular analogs for products and services.' (European Federation of Biotechnology, 1989)

Classical biotechnology, as well as modern biotechnology has basically used the same science-base; the knowledge and the application of genes. However, whereas classical biotechnology has restricted itself to the traits inherent to the species or to related species, and tried to enhance certain qualities by breeding, cross breeding and hybridisation technologies, modern biotechnology did not restrict itself to one family of species; it rather tried to find novel combinations using DNA from unrelated species. Genes of an onion, for instance, were used to improve saccharine production in sugar-beet. Genes of flowers were used in golden rice with its increased yield of carotene. That is why the term 'genetic engineering' is often used as an equivalent for modern biotechnology. Modern biotechnology is the epitome for techniques like DNA analysis, cell-fusion, bio-catalysis, bio-informatics, organ- and tissue-cultures, etc. The term, 'biotechnology' thus refers to a toolbox of techniques, applied in a range of fields, such as healthcare, diagnostics, agriculture (crop and cattle-breeding), foods, drinks, fine chemicals and environmental care.

This summation is certainly not exhaustive, the biotech toolbox is constantly filled with new tools. Molecular biology, for instance, is such a new technique, with a variety of applications. It ranges from 'cloning', which is basically 'making more of the same', to techniques to insert genetical information from one organism into another (unrelated) organism. These techniques are hidden behind concepts like: genetic modification and manipulation, genetical engineering, and recombinant DNA technologies.

3.6 Various technological aspects of modern biotechnology

The discovery of the DNA structure in 1953 has marked the prelude of a change, but the impact of that discovery became only visible when scientists managed to take out strains of DNA from one organism and insert it into another, thus, changing the genetic structure of the new species.

Especially the successful efforts to recombine DNA in novel products, has marked the change from classical biotechnology to modern biotechnology. After the first applications in the early 1970's there has been a true explosion of technologies and a constantly increasing range of biotech products and services. Still, even though modern biotechnology could build on a growing knowledge-base, and scientist increasingly improved techniques and equipment to modify the gene structure of new organisms, a true understanding was still a long way to go. Knowing the DNA structure is one step, but understanding the genetic information is another. Celera Genomics and the Human Genome Project have both set up projects to unravel the genetic structure of the human DNA, initially as rivalling groups, but in the end in close collaboration, involving research groups from many different countries. The research project was successfully ended early 2001 and set a mile-stone in genetic research. Having all the information of the human DNA structure has allowed scientists to enter the complicated relations between hereditary patterns and specific diseases, and thus to a new approach in (human and animal) health-care. Understanding the interaction between the DNA structure and cells is of the utmost importance in modern healthcare. Small parts of the DNA structure produce specific proteins which have a specific function within the organism. Research in the field of genomics mainly concentrates on the circumstances that trigger or activate gene-expression, and how these circumstances influence the results of a particular gene expression. Research also focusses on the differences that are brought about by external influences like metabolism and nutrition of the cell, the influence of drugs and other chemicals, and even the impact of psychological influences. In the future, these studies may reveal the secrets of the metabolism in small organisms, like cells, but also in larger organisms, thus giving a deeper insight in the nature of specific diseases.

> Craig Ventor, the director of Celera Genomics has taken an advance on this new approach in human healthcare. He was one of the five volunteers who provided the genetic information for the map of the humane genome and it was found that he had inherited a gene called *'apoE4'*. This particular gene is related to an anomalous fat-metabolism, which is known to be related to Alzheimer's disease. Craig Venter has started to use fat-reducing drugs to prevent Alzheimer's disease to develop.
>
> *Source: NRC/Handelsblad 2002*

Box 10 *Taking early advantage of the changing paradigm in modern healthcare*

Expectations on the ability of modern bio-technology to cure hereditary diseases are extremely high, especially in humane health care. It is expected that prevention and treatment of diseases, will increasingly be based on this new technological paradigm. It is expected that in the future the classical treatment of diseases, with broad spectrum chemical drugs, will be replaced by tailor made, personalised drugs, that repair certain defects in the hereditary structure of humans or prevents certain diseases to develop. It is generally foreseen that the impact of this new approach in treatment of diseases will be much stronger than the introduction of antibiotics in the 1940's.

Discussing the technological aspects of modern biotechnology is rather complicated. The basic principles may have a generic character, but the fields of applications differ so much, that it is fairly impossible to discuss all possible applications. The most important sectors where modern biotechnology is applied are in healthcare (human and animal), agriculture and food, fine chemicals, plant breeding and environmental care.

Bio-informatics are relatively new shoots at the biotechnology-root. This new technology does not work in a laboratory, but used computers instead, to build, combine and process huge databases. The unravelling of the human genome has resulted in a tremendous source of information. To make the full use of that data, one has to build huge, but well structured databases which contain all the information that scientists need. The better the information is organised, the better the scientific results, because research groups can easily find the data that they are looking for and can add the results to the same database. Bio-informatics provide the search-machines and the setup of the database. The second line of work in bio-informatics is to describe all the properties of proteins, enzymes and genes. One can compare this to a herbarium in biology. Bio-informatics make a detailed description of all the organisms and its elements.

Box 11 *Bio-informatics: a technology with high relevance in all fields of application*

However, the borders between sectors and technologies are rather vague. For instance, many new species of plants are bred whether to be used in medicine, food or chemicals. Animals have been genetically modified to produce specific proteins to be used in specialised foodstuffs, but also in drugs. Moreover, the bio-technological toolbox is constantly extended. New technologies are added time and time again. In the box opposite we have given the example of bio-informatics, the successful merger between biology and informatics. Bio-informatics have made available the properties and characteristics of organisms, proteins, enzymes and genes. It also has made available what already has been achieved in the scientific field. Bio-informatics have arranged information in such a format that it allows scientists to access data in a relatively easy way. It, thus, serves as a library to be used by all the scientists in modern biotechnology and it provides all the information needed to perform large-scale and high-speed analyses. However, it is clear that the use of the databases is not restricted to one single field of technology. The properties of enzymes and proteins are relevant in virtually all sectors of the bio-technological field. But also within each field of application there is an ongoing process of differentiation and specialization on the one hand, and a process of integration on the other. Combinatorial chemistry/biology is able to create large molecular libraries in relatively short time, through the use of high throughput screening technologies. Due to the greater availability of these large libraries -and here again one can see the importance of bio-informatics- one can test many molecules in a short time, and this has become one of the key technologies in novel drug-design.

Thus, the field is not only complex, but also under development, which makes every classification of fields arbitrary. Therefore, we have chosen to give a short discussion on recent developments in the sectors of human and animal healthcare, plant breeding, animal breeding, food industry, fine chemicals and environmental care

3.6.1 Human and animal healthcare

The first draft of the sequence of the human genome was released on June 26th 2000. The final version was published on February 12th 2001, Darwin's birthday. Even though world leaders spoke of a new era in science, the presentation was somewhat overshadowed by the relative small number of genes that were found in humans. Celera Genomics found 26,383 genes and 12,000 candidates, the academic institutes found 24,500 genes and have estimated that another 5,000 still may be expected. This is the more surprising, because much simpler creatures such as gapeworms (Caenorhabditits elegans) has already 19,000 genes; a tine plant as the sand-rocket (Arabidopsis) has almost 26.000 genes; the fruit-fly (Drosphila melanogaster) 13,600 genes; and a simple single-celled organism like the bacteria Pseadomonas, which has already more than 6,000 genes.

> In May 2000 gene-researchers from all over the globe had a conference in Cold Spring Laboratory, New York and discussed the number of genes a human would have. During dinner, they started speculating and decided to place a bet. The stake was small; only one dollar per person. The kitty would be taken by the person who was closest to the final outcome. The lowest educated guess that night was 27,000 genes and the highest 153,000. The bet started to live its own life on the Internet and the estimations were higher and higher. The average on the first night was 62,000 genes, but it had increased to the average of 72,000 in the last three months of 2000.
>
> *Source: Vermij/NRC Handelsblad 2001*

Box 12 *Gene researchers place a bet*

The initial expectations regarding the number of genes were so much higher than the final result, because scientists have build their expectations on fragments of DNA, which enhanced the chance to count the same genes several times. But scientists have also underestimated the subtlety of genes. It was thought for a long time that each gene would lead to the production of one single protein, but that is not the case. Genes can produce several proteins. The gene in the liver can produce protein A, while the same gene in the kidneys produces protein B; it all depends on environmental factors.

Yet, the relevance of this milestone discovery in biology is enormous. The hereditary information of humans rests on 23 chromosomes, and this packet is double present in the double helix structure in each cell of the human body. Each chromosome contains a string of compact folded DNA. Only a small part

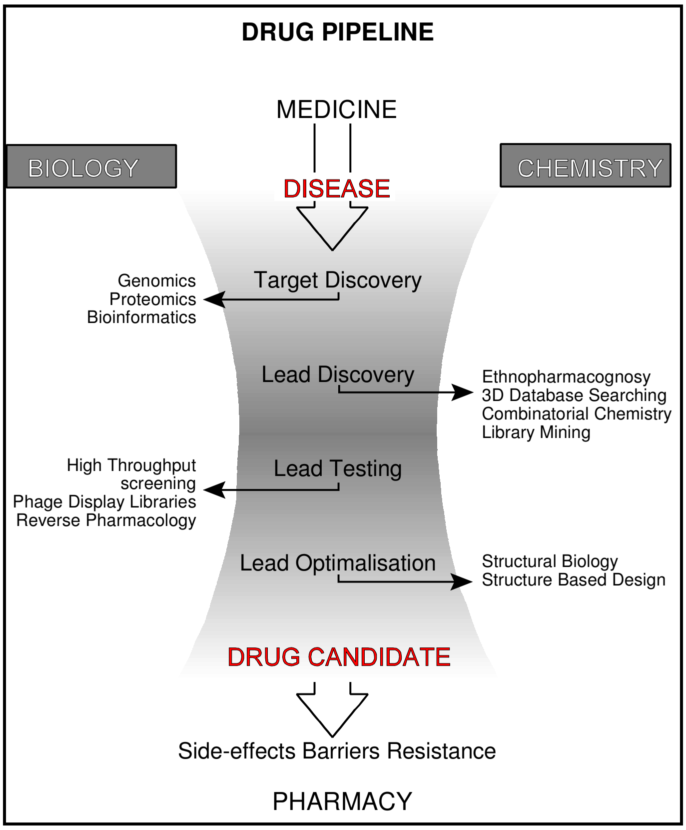

Figure 35 *The role of the various disciplines and technologies in the modern approach of drug discovery, from target-discovery to lead optimisation*
Figure based on: Moret, Department of Medicinal Chemistry, Utrecht Institute fro Pharmaceutical Sciences (UIPS)

(approximately one percent) of the human DNA is built with genes. Genes are usually defined as a string of DNA containing the code for a specific protein. No single person has a DNA sequence which a perfect match to the results of the human genome as it was published on February 12th. The relevance of the publication of the human genome is that it constitutes a source of reference for deviations from the general pattern, which are related to specific diseases. For instance, a comparison of the gene-activity in cancer-cells and healthy cells can help to identify the genes that play a role in cancer. The availability of the genome sequence in a variety of living systems will accelerate the knowledge and understanding of the molecular basis of diseases. This knowledge will be derived from the differences in the gene expression between normal and disease conditions.

The key step in current drug research is the selection of targets with the highest probability of relevance to disease pathogenesis. Genomics is especially concerned with the understanding of the relationships between genes and diseases. The ultimate goal is to find molecular markers for diagnosing and monitoring disease progression, and to locate potential targets for therapeutic intervention. Therefore it is necessary to identify which particular genes are abnormally expressed in diseased tissue. However, not all abnormally expressed genes are necessarily involved in the disease. Genomics alone provides only limited information about the level of protein patterns and activity in the cell. Characterisation of the full picture of expressed genes and the full dimension of proteomic diversity will fill the knowledge gaps in order to understand cell differentiation and the perturbations which are responsible for diseases. A better understanding of the molecular mechanisms of transcriptional and translational control at the different stages of cell differentiation and cell growth is therefore needed. Proteomics is an increasingly powerful tool in drugs discovery, as it monitors directly the level of protein expression in cells, where disease processes are initiated and where drugs can act. It will facilitate the identification of the protein molecules which are associated with disease processes and elucidate new therapeutic targets for small molecule drug discovery (cf. Wilting, 2001, pp. 160-5).

The application of modern biotechnology in health care will have tremendous implications for preventive, diagnostic and therapeutic medicine. The human body is seen as a large organism with a wide range of functions, controlled by metabolistic processes, and guided by genes. Dis-functionality or defects in genes, which may cause disease, especially hereditary disease, can be diagnosed in an early phase. It is foreseen for the future that large scale scanning programmes, aimed at the detection of the genes may help to diagnose disease before it gets active. This is a major shift in preventive healthcare as well as in diagnostics. The field of attention is in a process of transition from symptom-based to constitution-based diagnostics.

A rather similar change of the technological paradigm is to be seen in drug development. The aim of the classical innovation process in drug-development was to find a specific chemical compound with special effects, often to be used in a range of applications. The aim of modern biotechnology is to find new targets for genome information first and then to 'tailor' a drug to interact with that specific target. Thus, for the effective treatment of diseases with drugs one has to identify targets like receptors, hormones, enzymes or growth factors, that correspond with a specific disease.

Genetic research is especially used in the early phases of drug-development to detect targets which are related to a specific disease. If the relation between a certain protein and a disease is known, one can look for compounds that activate the organism to make this protein, or in case the protein is produced in too large quantities, to stop the making of that specific protein. Bio-informatics provide the databases and knowledge to analyse gene expression, genetic defects and gene-mutations, which are known to be the cause of that specific disease. It makes it much easier to access and analyse huge quantities of data and it will help to bring down costs in drug development. It is expected that healthcare will gradually move from cure to prevention, and customising medicine to individual needs.

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

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

The shift of the technological paradigm in modern healthcare has opened the view to most promising perspectives, yet, the technologies are still in an infant and experimental stage. Gene therapy, for instance, is based on the natural ability of the body to bring genes to expression, which will strengthen or replace the function of a dysfunctional gene. Gene therapy is especially aiming at the treatment of chronic diseases. Also very promising for the treatment of diseases or injuries is cloning of specific tissue, because the human immune system will easily accept these new cells. The main technology is the transplant of a cell nucleus in a germ cell from which the nucleus was removed, which is the beginning of the development of new cell structures. Xeno-transplant is the use of tissue or organisms from animal origin in humans, to replace defect organisms in the human body. Tissue engineering is the cultivation of organisms or parts thereof in a medium, outside the body. This technology -again- has the advantage that the immune system does not reject this new bred tissue as foreign, but recognises them as substances naturally occurring in the body. The use of transgenic animals in health research gives much insight in the development of diseases. Transgenic laboratory animals are bred for this purpose. In laboratory animals specific genes are eliminated. The use of plants, animals and cell cultures in the production of drugs is increasingly important. Transgenic animals for instance, whose gene structure has been altered, deliver the right compounds for the production of drugs. Similar attempts are made in plants, but these developments are in a very early stage of development. (Cf. Enzing, 2000)

3.6.2 Plant breeding

Improvement of crops has traditionally been an important field of attention in classical biotechnology. Darwin's ideas about the variation of plants under domestication have fallen in fertile ground at the Wageningen school for agriculture, which opened its doors in 1876. Darwin's ideas provided a perspective for a new line of thinking about improving desired properties in crops, and many breeding technologies came under rapid development. The Dutch starting position was already most successful, but as a result of these research efforts the Dutch performance in several crops was among the best in Europe. Even today Dutch seed-companies are among the world leaders.

The new set of bio-technological tools, such as rDNA technology has allowed breeders to cover a much wider range of activity than ever before. A number of molecular genetic technologies have been developed and implemented during the past thirty years. The multiplication of plants, which was usually done by pollinated seeds or by a variety of strike and grafting techniques has undergone considerable changes. A technique under construction for instance, is vegetative reproduction by seeds. The advantage of this technique over classical technologies is that the plant is less vulnerable to disease and that its storage life has increased considerably. Multiplication of plants by several cloning techniques is, however, just another orientation in plant research. The alteration of properties of plants through genetic modification is the most eye-catching direction, not in the least because of public resistance to these technologies in several European countries.

Genetical modification of plants has started in the 1980's, and the first experiments were attempts to make plants resistant to herbicides, pesticides and fungicides. Furthermore these experiments were aimed at an increase of yields. These experiments have been most successful. A substantial acreage in the US, Canada and South America has already been planted with genetically modified crops, especially soybean, maize, cotton, rape (colza), tomatoes, potatoes and tobacco. Europe is still in the process of field trials, and allows under strict conditions experiments in (sugar-) beet, lattice, cucumber, apples, strawberries, carrots, aubergines and several species of cabbage.

Usually a division is made between several 'generations' of genetical modification. The first generation has mainly concentrated on the producers of crops. The research efforts were aimed at increasing yields, decreasing the use of herbicides, pesticides and fungicides, and protection against disease, low temperature, drought and frost. The second generation aims at improving the plant, seen from the perspective of customers and environmental care. 'Golden rice' is an excellent example of such a crop. Its increased yield of carotene helps to prevent from blindness, which is especially relevant for the underdeveloped countries. Nowadays' objectives are much more oriented to the final customer and it is expected that s/he will benefit from improved taste, an extension of the plant's shelf life or improved nutrition value. However, this line of research is still in its infancy. That is also the case for plants that produce pharmaceuticals and other high value compounds. A quarter of today's medicine contains compounds of plant origine and the first experiments to increase these active compounds are most promising, not in the least because the risk of carrying over disease from plants is much less than it is from transgenic animals.

Next to multiplication and modification of plants, modern biotechnology is also used as a genetic marker. This allows breeders to observe properties of a plant before it has reached the full-growth stage. Marker-assisted breeding is especially important, because it can bring down development time with several years, especially for slow growing crops.

Plant research is also very important in current genomic research. The unravelling of the gene structure of the sand-rocket (Arabidopsis thalianna) and rice will provide a better understanding of life processes in plants and the interaction between plants and their natural environment, which will be of great importance in food-production as well as in health care (cf. Van Tunen, 2001; Enzing, 2000).

3.6.3 Animal breeding

A common breeding technique for life-stock in agriculture is artificial insemination, a technology which was developed in the mid-1930's and improved ever since. It allowed breeders to raise high-class bulls. To give an idea of the effectiveness of the technology: natural impregnation was usually limited to an average of 200 calves per bull, whereas artificial insemination allowed for 10,000 calves. A champion bull even impregnated 60,000 cows. An additional approach in cattle-breeding was developed from the 1960's.

Under the influence of economical dynamism the question was raised how to control the share of fat and proteins in milk. A study had demonstrated that the level of fat and protein were both regulated by hereditary factors. New breeding systems were developed, which used the full potential of artificial insemination and combined them with new insight in population genetics. A boost to these developments was given when computers came available to run large scale statistical tests and genetic analysis.

Artificial insemination has increased the yield per bull tremendously. However, the yield from the female line in breeding was limited to the gestation period of the cow. From the 1970's on a new technology was introduced: the transplant of embryos. This technology entails that cows with extraordinary traits and performance receive a hormone boost. As a result the cow will give several egg-cells, instead of one. Five days after the insemination the fertilised egg-cells are harvested and implanted in other cows. Instead of one calf per year an extraordinary cow can give several dozens of calve in the same time period (Bieleman, 2001, pp. 138-49)

The technologies discussed in the above have demonstrated that the breeding of cattle has gained an increasingly scientific foundation. A good eye for promising properties changed into the consultation of track-data and it is only a matter of time before selection is an even more sophisticated combination of tacit and codified knowledge. The public debate has often concentrated on genetic modified breeding methods, but the classical breeding technology still offers sufficient room for further development. Furthermore, genetic uniformity is not very desirable in life-stock breeding.

A specific branch in biotechnology is the unravelling of the genome structure of life stock. International consortia have set up programmes such as PigMaP for pigs, BoVMaPE for cattle, ChiCKMaP for chickens and other programmes for sheep, horses, turkeys, cats and deer. High potential gene-structures can be identified, which is most valuable information for breeders. Next to that technology new forms have been developed like in vitro fertilisation and in vitro nursery of embryos. These techniques are used for a number of reasons. (i) to improve the efficiency of the selection process, (ii) to use species with specific genotypes, (iii) to monitor the genetic structure of populations, and (iv) for the extension of gene migration in unrelated species. A second set of breeding techniques is a variety of reproduction techniques, such as cloning.

A most important development in the breeding of animals is the alteration of the genetic structure. An interesting example in the Netherlands is to be found in the bull Herman, who was bred in the early 1990s by the Pharming group as a genetically modified animal. His female offspring has a altered gene structure, which makes her milk easier digestible for humans with a specific intestinal disorder. Several medicines with lactoferine, isolated from the milk of these cows is in various stages of clinical testing. Pharming has also experiments with the milk of genetical modified rabbits. However, most research on transgenic animals is aimed at the breeding of laboratory animals to be used in medical experiments.

A second reason to breed genetical modified animals is to make them suitable as organ donor for xenotransplant. This technology is not allowed yet, because so much risks are involved, but research in this area is currently under development, however, under a very strict regime. The third reason to consider the genetical modification of animals is to obtain better domestic animals and fish. Possible targets are: disease and pest resistance, leaner meat in the production of pigs, pigs that can metabolise cellulose, sheep that can utilize cysteine-poor feed, frost resistant salmon (using anti-freeze genes from cold-resistant fish from

Polar seas), large size salmon, etc. However, transgenic breeding techniques are not used in cattle for food production, firstly because classical breeding technology still offers a range of possibilities, and secondly, because there is fierce resistance in the public regarding the modification of animals for food production (Tramper, 2000, pp.146-9).

3.6.4 Food industry

The food industry and food research can benefit tremendously from modern biotechnology. Especially the recent revolution in genomics has a major impact on food and nutrition research. Nutri-genomics, a technology which incorporates the new generation of applied genomic's tools, embedded in food and nutrition sciences, is rapidly developing. The embedding in 'classical' sciences, and the strong position of many of these (e.g. microbial physiology and human physiology and epidemiology) provide an excellent base for turning nutri-genomics research into functional food applications. Moreover, many other options for new, genome-based approaches in food research are being explored, ranging from advanced screening systems to find micro-organisms with improved functionality to more powerful analytic tools for establishing food authenticity (van der Kamp, 2001).

Genomics research thus holds high promises for the food industry. Its main focus is the study of the role of the DNA in normal life process (infancy, childhood, adolescence and adulthood) and the influence of external factors in increasing of decreasing the pace of certain metabolic routes that are embodied in normal development. A deeper understanding and insight in the structure and function of certain essential nutrients and the relation food / health may offer a platform for new types of enriched nutrients.

In food-research we find several developments. First there is the development of novel foods. There are basically two directions: functional foods or nutriceuticals and foods which have new characteristics through genetical modification (see the example of golden rice). Nutriceuticals are foods which have an extra active component. These foods are highly nutritive or have a clear health effect for specific groups. Functional foods can be developed for many purposes, for instance for the decreasing of cholesterol levels in blood, strengthening of bones, improving mental functions such as alertness, enhancing satiety, improving skin quality. The main challenge for this line of research is the selection of food grade components and optimal levels that impart a significant positive effect without having any negative side effects, since foods are no drugs (ibid., 143).

Biotechnology has also a wide-spread reach in production processes. In the context of food safety programs one aims at monitoring all the steps in the food-production chain. Here biotechnology offers a wide range of diagnostic kits to monitor food quality, hygiene and contamination. These diagnostic kits replace the classical and physical techniques of analyses (cf. van der Kamp, 2001).

3.6.5 Fine chemicals

The twentieth century has been the age of chemistry. 'Plastics', nylon and other synthetic materials and fibres have changed the nature of so many products. These new products, for instance synthetic fibres used in garments, could be produced at low prices compared to natural fibres and thus chemistry has considerably contributed to the spread of prosperity. Chemistry was a true 'blessing', but it had its drawback. Chemical processes used to be very polluting and chemical waste was a heavy burden for the environment. That is why chemistry is often criticized by the public and chemistry was regarded to be a mixed blessing. The chemical industry is well aware of these problems and has invested in new approaches. The use of enzymes in chemistry offers such a new approach. Not that these processes are less polluting than classical chemistry, but the waste is easier biological de-gradable. The use of enzymes in the chemical industry is increasingly important, because, being more specific, they lead to better products, and are also easier to handle in production. An example is the production of 6-amino penicillanic acid, which used to be produced in three steps under rather extreme circumstances. By the use of enzymes this process is now a one-step process under much milder circumstances, which puts less pressure on the environment as well as on energy consumption. In this sense the use of enzymes in fine chemicals is expected to lead to lower costs, which makes this technology extra attractive.

Biocatalysis can be an attractive alternative to classical chemical conversion under certain circumstances. Factors to be considered are for instance (i) availability, purity and costs of reactants and other medium components, (ii) the number of reaction steps in the processes (iii) selectivity and yield, (iv) reaction conditions, (v) ease of product purification, (vi) final product quality and of course (vii) environmental aspects. Especially if the use of biocatalysis can reduce the number of process-steps, one has a strong argument to favour the use of a biocatalyst over conventional chemistry, even though the latter is a strong competitor (Tramper, 1999, p. 56). Several examples of 'green routes' in chemical processes are available yet. We already mentioned how biocatalysis of 6-amino penicillanic acid is used in stead of chemical conversion, but there are also examples where we find applications which are related to everyday's product. Blue jeans thank their name to the blue dye-stuff indigo. However, the indigo-dye process is a very aggressive and polluting process, which is the reason why a new 'green' process has been developed for the blue jeans' dye-stuff (cf. Tramper, 2001).

3.6.6 Environmental care

The natural environment is a precious gift of nature, which needs to be preserved. Biotechnology offers several technologies to prevent environmental pressure, it helps to detect pollution and it can be used as a cleansing of polluted air, water, soil and solid waste. In cleaning technology, biotechnology is used to break down nitrate, phosphate, metals, chlorinated hydrocarbons and certain toxic substances or to concentrate these substances after they have spread in the natural environment. Engineered micro-organism are especially suited for these purposes. They work faster, more precise and safer than their chemical counterparts. In general, these micro-organisms and bacteria are engineered in a classical way, rather than by genetic modification.

A new perspective is offered by the use of genetical modified plants for bio-remediation. Thus, biotechnology has proven to play an important role in solving environmental processes. In essence, used is made of bacteria involved in the natural cycling of material. Human activities often bring these cycles in unbalance. By stimulating the natural activity of micro-organisms in designed environments (reactors) or in-situ (mainly for soil remediation) it is to a large extent possible to enhance these natural cycles, and bring them -more or less- in balance again. Extra advantages of bio-technological applications are the absence of the need for large amounts of auxiliary materials and the high affinity of micro-organisms towards substances which allows purification down to desired low concentration levels. However, for concentrated wastes it can be more beneficial to combine physical-chemical treatment (combined with material recovery) with a biological process.

A special application of biotechnology in environmental care is the use of immuno assays, basically monoclonal and poly-clonal antibodies, which are developed to measure specific kinds of contamination and pollution (cf. Heijnen, 2001).

3.7 A taxonomy of innovations revisited

How do the developments, outlined in this chapter relate to our discussion of different types of innovation that we have identified in section 2.1.3? Is it possible to categorise them under one of the typologies we discussed so far, or do we need an additional classification system? Furthermore, are there important differences between the two sectors under review, and are there differences stable over time?

It is fairly impossible to give a straightforward, unequivocal answer to these questions. First, telecommunications as well as biotechnology are containers for a range of different technologies and products. In the telecommunication system we can distinguish between different type of equipment (transmission, switching and end-user equipment) and different systems to build and operate a network. Furthermore we can break down equipment to their components, like integrated circuits, wires, microphones, coils and batteries and in associated products. Especially in mobile communication we find a range of gadgets and accessories like bags, front panels, but also software-driven gadgets like ring-tones and displays. In biotechnology the field is even more complicated, because it ranges from applications in the smallest cellular organisms to the complex world of plants, animals and human beings. Biotechnology is furthermore used in agriculture, breeding of life-stock and plants, food-processing, healthcare, environmental care and chemistry. Thus an unequivocal answer is not possible, unless we keep the different characteristics of technologies, products and services in mind.

A second complicating factor is that in both technologies an important change of the technological paradigm has taken place. Telecommunication made the switch from analogue technology towards digital technology. Biotechnology made a similar kind of switch whet it succeeded to extend its search-directions, through the capacity to insert strains of DNA from one organism into another unrelated organism. These changes have taken place in the course of the nineteen seventies and eighties.

A third factor that complicates a general, yet unequivocal answer is that the technologies and products under review are hard to compare with general industrial products, like cars, televisions, tooth-pastes or washing detergents. These latter types of products are liable to the rules of supply and demand, whereas telephony was organised as a monopoly, which excluded the influence of market forces. The market for telecommunication-end-user products was only opened in the early nineteen-nineties. The same was basically true for network-equipment. Telecommunication companies had a stable group of customers, and the national telecommunication industry was tied so much to the national operators that the relations could be considered as an integral part of the monopoly. The character of biotech innovations is also hard to compare with innovations in regular industrial products. Biotechnology provides insight-knowledge of how to apply techniques and use them in such a way that yields are highest. The fourth complicating factor is that much of the innovations done in the early days of the technologies under review were not so much the result of intended research efforts, but rather the result of serendipity and trial and error.

In our view, Whitley's classification scheme is the richest, especially because it has used discerning variations to capture the nature of the innovation process. However, his starting points mainly focus of the capacities of the firm and the characteristics of a product in a competitive market. Sarmento-Coelho's model lacks the richness of Whitley's model, but her starting point better fits our purposes, because she mainly focusses on the research process and its outcomes. We propose to combine the two approaches and to distinguish between incremental, artisanal, progressive and radical innovations. In the table below we have outlined the major characteristics.

	incremental	**artisanal**	**progressive**	**radical**
Frequency	relatively high	high/low	low	very low
Investments	medium/ low	medium/ low	large	very large
Research results	short-term	medium-term	medium-term	long-term
Uncertainty about the nature of innovation	low	low	medium	high
Uncertainty about the user	low	medium	medium	high
Modifications	minor	minor	large	(not applicable)
Implementation	short-term	short & medium term	medium term	long-term
Reliance on codified knowledge	low	medium/ high	medium/ high	high
Reliance on complex, varied knowledge base	low	medium	medium/ high	high

Detail in planning	low	low	medium/ high	high

Table 20 *Classes and characteristics of innovations, based on the originals proposed by Whitley (1998) and Sarment-Coelho (2000)*

Incremental innovations in this view are mainly minor improvements and modifications to existing technologies and products, within a known technological framework, Incremental innovations are to be seen as an adjustment to variations in existing technologies. It entails innovations in products as well as in processes. They include design and re-design of existing products, variations on and improvements of services and operating procedures.

Artisanal innovations are only partly the result of organised research efforts They are rather the result of learning by using by skilled craftsmen. New insights usually arrive from the shop-floor where highly specialised technicians bring forward new ideas, improve the capacity of existing systems and improve quality. Artisanal innovations distinguish themselves from incremental innovations in that they involve a high degree of tacit knowledge. Reputation, quality, craftsmanship and a sharp eye for customer's demand are the main characteristics of artisanal innovations

Progressive innovations entail large modifications to existing products, systems and technologies. Doing the same in a different way, but better, more precise, more reliable and more cost efficient.

Radical innovations refer to totally new products, technologies and methods. These may even appear within the existing framework of generic product-groups, but their reach is such that their application is totally new. A new drug that can effectively fight and cure cancer or Alzheimer's disease could be an example of such a radical innovation within a generic product-group (drugs/medicine).

With this classification system we can identify the characteristics of the innovations that have taken place in the two technologies under review. We have chosen some of the most important innovations in each of the two sectors.

For telecommunication we choose six technologies that -by and large- cover the major developments in telecommunication. We start with the classical three technologies (transmission, switching and end-user equipment. We furthermore, added three technologies that have gained importance especially after liberalisation of the telecommunication sector.

The table below is divided over four time-columns, each representing an important era in telecommunication development. At the turn of the nineteen eighties we have inserted an extra column in which we have classified the change of the technological paradigm. However, we have to keep in mind that the change from the analogue-electromechanical paradigm to the digital-optical paradigm did not take place in each of these technologies at the same time. The first applications in transmission technology were already in place in the nineteen seventies, while digital services in mobile communication only emerged in the nineteen nineties.

	1900 - 1950	1951 - 1980	digitali-sation	1981 - 1995	1996 - today
network and transmission equipment	incremental artisanal	incremental	progressive	incremental	incremental
switching equipment	n.a	incremental	progressive	incremental	incremental
end-user equipment	n.a	incremental artisanal	incremental progressive	incremental progressive	incremental
mobile equipment	n.a	artisanal progressive	progressive	incremental progressive	incremental
network services	incremental artisanal	incremental /artisanal	progressive incremental	incremental	incremental
value-added services	n.a.	n.a	incremental /artisanal	incremental artisanal	incremental artisanal

Table 21 *Technological innovations in a selection of telecommunication technologies (1900 - today)*

The change of the technological paradigm, from analogue to digital technology is first and foremost to be seen as a progressive innovation. Some will argue that the introduction of digital technology was a true act of creative destruction in the Schumpetarian sense, outdating analogue technology in one blow, and therefore digitalisation should be addressed as a radical innovation. We believe that is too much honour. Digital technology in the telecommunication network was basically doing the same (providing telecommunication services) in a different way. Initially the telecommunication services did not change and it took substantial time to develop specialised applications that were previously not available under analogue technology. Innovation in end-user equipment is to be seen as a mixture of incremental and progressive innovations. In recent years a huge body of knowledge has been developed in digital technology, so that the step from analog towards digital has been much smaller in end-user equipment than in switching or network technology. Furthermore, the body of knowledge about digital equipment was not only developed in telecommunications, but also in adjacent fields as television- and computer-technology. The same is basically true for network services. These services came widely available with the liberalisation of the telecommunication market and the need for companies to communicate data. Innovativeness in value-added service is however, a different story. This particular product is based on the use of advanced software in a digital environment. As such it is a variation of the use of software in adjacent technologies, and developments in telecommunications have kept pace with developments in adjacent fields. However, especially since these services have been liberalised, the importance of craftsmanship has increased. For many companies and private subscribers the additional services are as important, if not more important than the basic features. The company that manages to develop the best fit between price, quality of services and customers' demand will have the trump-cards for the largest market-share.

During the period of analogue technology, innovations were mainly to be characterised as incremental and artisanal. Especially the early days of telecommunication, when experimenting was a trial and error process, the artisanal component was very important. Telecom-technicians were recurrently able to improve the capacity and reliability of the telecommunication system, mainly building on tacit knowledge, good experience and a creative mind. The more the system was integrated in a network with a nation-wide coverage, the more it was needed that these technicians coordinated their efforts in research and development departments. After the introduction of digital equipment, innovation was by and large, dominated by incremental innovations. What happened abroad also happened in the Netherlands and the further development of the system was a gradual extension of its reach (for instance towards multi-media) and a gradual extension of speed and capacity.

	1900 - 1950	1951 - 1980	rDNA technology	1981 - 1995	1996 - today
Healthcare			radical/ progressive		
insulin		progressive artisanal		progressive	incremental
penicillin	radical	progressive incremental		progressive	incremental
orphan drugs				progressive radical	progressive radical
diagnostics				progressive	incremental progressive
Agriculture			progressive		
Plant improvement	incremental artisanal	incremental artisanal		progressive artisanal	progressive artisanal
Animal improvement	incremental artisanal	incremental artisanal		progressive artisanal	progressive artisanal
Food processing			progressive artisanal		
foods	incremental	incremental		incremental artisanal	incremental /artisanal
novel foods				progressive artisanal	progressive artisanal
diagnostic kits				artisanal progressive	artisanal progressive
Chemistry			progressive	progressive	progressive
Environmen-tal care			progressive radical	progressive radical	progressive radical

Table 22 *Technological innovations in a selection of bio-technologies, 1900 - today*

The table for biotechnology has a slightly different architecture from the one used in telecommunication. The reason is that bio-technological processes have been used in broad range of technological fields, each containing many different product-groups, each with its own characteristics. For instance, in healthcare we cannot speak of one single type of application. The unravelling of the human DNA structure has allowed to acquire a deeper insight in the function of the human body and has brought about a new approach towards disease and its treatment. A shift is underway from cure, through treatment with medicine, towards prevention, through an alteration of the genome structure. This is indeed a most radical change in an existing field technology. However, this is still a future perspective, not today's reality. Today's reality is that several groups of classical drugs have been re-designed, using modern bio-technological techniques, such as in the production of insulin of antibiotics. These products are on the market and they are to be seen as a 'fist-generation-application'. The functioning of the drugs has not changed, but the active substances are derived from a different source. Insulin is no longer harvested from the pancreas of cattle or pigs, but synthesised from genetically modified bacteria. It basically fits the classical pattern of cure, rather than it has a function in prevention. The same is true for the design of new drugs to fight cancer, chronic diseases and hereditary diseases. The starting point is cure, but there is an increasing use of the body of knowledge that is based on the genetic structure of the human body. Thus, one can identify several generations in biotech healthcare applications and each generation has its own dynamism. If we follow the developments in penicillin and antibiotics over time, we can say that Fleming's initial invention of penicillin was a true radical innovation. The knowledge acquired from his first applications has led to a range of new antibiotics with the capacity to fight specific types of infections. In terms of innovativeness these are progressive innovations, although they tend to become incremental innovations, because they are increasingly developed as variations within a known framework. Modern biotech techniques have allowed to harvest the active substances more efficiently and, again, this was a progressive innovation. Today the properties, functioning, and production of antibiotics are well defined, so that the character of innovations in this particular field has gradually moved from progressive to incremental innovations. This is not the case for the development of orphan drugs[4]. Although these are also rooted in modern biotech, they are developed within a different framework, wherein the genetic structure is the starting point for research, rather than the fight of symptoms. The innovations in this field have a more progressive and radical character. Thus, it is impossible to value innovations in healthcare under one denominator.

A second difference is that it is impossible to trace developments over time in many fields of application. In fact, penicillin is one of the exceptions, because this drug was already developed using classical biotechnology. The same holds for breeding-technology in plants and animals. However, in chemistry this is not the case. Environmental care is a marginal case, because classical biotechnology was traditionally used, for instance in composting.

The applications in healthcare have mainly a progressive character, with some radical breakthroughs, but also a large degree of incremental applications, especially when a new technology has crystallised in a solid body of knowledge (as in the case of antibiotics).

In agriculture we find different characteristics. In classical biotechnology it the combination of incremental and artisanal innovations. The character of innovation has changed when RDNA technology came available, but the artisanal component remained very important. The reason is that much of the knowledge used in agriculture has a rather tacit nature. No doubt, in her/his decision to toss the hay or to bring it in, the farmer will use the official weather forecast, but s/he will also rely on the signals that s/he has learned to value through past experience. If the 'wind is in the wrong corner' or the sky gets cloudy, s/he will rather ignore the official weather report and trust on his/her own evaluation. A good example is to be found in breeding techniques in Friesland. Methods of artificial insemination have been well developed and the properties of breeding bulls are known in detail. Yet, farmers do not base their breeding programmes on the well-described properties of the bull, but on the tacit knowledge they hold on the cows. The farmer knows which match is the best for a particular cow, and s/he will not hesitate to combine the properties of a low-ranked bull, if s/he feels that this will result in a better result that in a combination with the highest ranked bull. Her/his expertise is rather based on tacit knowledge about the properties of the cows, that emanates from experience, than on the codified knowledge about the properties of the breeding bull (cf. van der Ploeg, 1999).

In food technology we find a similar pattern. Most of the innovations in food-technology were incremental variations within known technological frameworks, and even after the shift of the technological paradigm, this has not radically changed. Most of the innovations in food-processing are incremental, although the artisanal share is increasing. Quality in taste, quality in substance, and creative

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[4] Orphan drugs are developed for rare diseases. For the pharmaceutical industry it was commercially not interesting to develop drugs for these rare diseases, because the costs of development could not be recovered from sales. However, through a change in the patent regime it has become much more attractive to develop orphan drugs, because it grants the company extended monopoly rights.

craftsmanship are increasingly important. In novel foods, which balance on the overlap between food and pharmaceuticals, the artisanal factor still is important, but here the progressive character of innovations is stronger. Developments are about to disclose an entirely new field, with many still unknown properties. The same basically holds for diagnostic kits which are used in food production to safeguard hygienic standards and detect contamination. These kits are tailored to measure and are better suited to detect contamination than the classical chemical kits.

By and large we can say that the bulk of technological innovations in telecommunications has an incremental character, gradually building on an existing technological framework and gradually extending that body. The change of the technological paradigm was a progressive innovation. The initial applications, especially those that helped to disclose the secrets of technology are to be seen as progressive innovations, but the more the technological framework was understood, the more the innovations tended towards an incremental character. Innovations in biotechnology rather have progressive character. A multitude of new applications have been developed in many technological fields. To use a metaphor, modern biotechnology has exploded like the dazzling of fireworks. Each new application is launched like a rocket and each trace of fire has sparked a new explosion of applications. The science-drive in biotechnology is very strong. The strength and elasticity of the fibres in a spider's web, for instance, have inspired scientists to modify goats with spider genes, because the proteins in milk have a strong resemblance to the proteins in spiders' silk. These experiments are most promising, even though the scientists have only limited notions about the future application of the technology. The reward is in extending the borders of knowledge, the commercial exploitation is a different matter. Each new application has disclosed new fields and allows for new combinations. This is an ongoing process and we expect that this process will continue. The basic principles of the genetic structure are hardly understood, let alone the reactions they bring about in organisms. Especially in agriculture and food-processing there is also a strong artisanal element.

Chapter 4: Early developments 1850 - 1945

> Historical small events may have large implications and can even culminate to lock the market in to the monopoly of a possible inferior technology
>
> *(Arthur, 1994, pp. 14-5).*

4.1 Introduction

A well-developed technological and scientific knowledge-base is an important asset and precondition for a country's innovative performance, but it is certainly not the only one. Archibugi and Michie have argued that technological change and innovation should be explored within the social fabric in which innovative activities are actually developed and used. Here we find nation-specific factors to play a crucial role. Some of these factors have an outspoken institutional character, such as the education system, the financial funding system, public support to industrial innovation, rules and regulations and technology-support schemes. Others are rooted in history, and concern the culture, size, language, and dominant patterns of education and vocational training of a nation. Crucial to the definition of a national system is how the different parts, such as universities, research centres, business firms and so on interact with each other (cf. Archibugi and Michie, 1997, p. 123).

The institutional structure in which innovation activities are embedded, may be encouraging for the innovation process, but it may also entail obstacles. Each element of the institutional environment is like a two-sided medal. For instance, governmental influence may on the one hand be supportive for innovation activities through funding schemes, tax-measurements and other incentives. On the other hand that same government may hamper the process through its system of laws, rules and regulations. Thus, government stimulates the exploration of the borders of science and technology, but government also sets limits on how far to go. In biotechnology we find clear examples of government-rules, restricting several areas of research and we will discuss these in more detail in the chapters still to come.

An integrated part of the system of laws, rules and regulations is the enforcement-system. How do regulatory agencies perceive their task in a field which is so dominated by uncertainty? Are they 'going by the book', or do they have a more lenient attitude towards novelty (cf. Bardach and Kagan, 1982; Oosterwijk, 1999). In other words, the existence of rules and regulations is one thing, but the way in which they are enforced determines their effectiveness.

A similar field of tension is present in the academic performance of a country. Strong academic performance is not by definition supportive to the innovation system. Imagine an academic system which strongly values regarding academic independence. Such an attitude may keep an arm's length distance to business and industry to safeguard scientific independence. The academy in this case may be strong in the generation of knowledge, but weak in the dissemination of that knowledge towards business and industry. This may keep a country's overall innovative performance low. Thus, not only the setup of the system, but also the functioning of that very system in daily practice determines the effectiveness of academia in the innovation process. Similar remarks can be made for the funding structure, the labour market, the education system and the research structure.

Culture, institutions and organisations, especially how they have crystallised in societal institutions are not the result of a carefully designed blueprint, but rather the result of historical trajectories, incidents and accidents which have paved the pathway to the institutional and cultural setup as we know it today. Decisions once taken in the past may have strong implications for the development of the system itself and the balance between sub-systems. It is the process of interplay between the sub-systems that provides the system with its dynamism. Thus, to understand the setup and functioning of the national sectoral system of innovation it is not enough to go over the current systems with a fine-tooth comb. For a true understanding we have to study how it has developed over the years towards its current state. History matters, and for a good understanding of today's technological, organizational and institutional setups, we need to identify the events and initial steps along the path that ultimately has led to a specific sectoral setup as we know it today.

Path dependence and increasing returns are important notions for the development of a national system of innovation. Small events may indeed have far-reaching implications for the setup of the institutional system, but also for technological trajectories. In this chapter we will discuss early developments in the sectors under review.

In the telecommunication sector we will discuss how the telegraph and telephony systems from their initial start in the mid-nineteenth century have developed towards the system as we know it today. The experiences gained in the early development of telegraph services, and the organizational setup of the State Telegraph Service, have strongly influenced the mind-set for the introduction of telephony. Rather than telegraphy, which was a nation-wide service, telephony was organised as a local service, instrumental to telegraph services. The initial telephone services were organised locally and, even though the national PTT was founded at the end of the nineteen twenties, the local orientation has been a relevant influence, even into the nineteen sixties.

The history for the biotechnology sector is not so unequivocal, because modern biotechnology has only started in the nineteen seventies. We will start our discussion at a much earlier point in time, at the end of the nineteenth century, when scientific discoveries layed the foundations of several important genetic, biological and chemical principles. This new knowledge-domain has unravelled, disclosed and codified the scientific principles that were only known as a tacit-kind of knowledge to experienced users. This has led to an increased production, especially in agriculture, which in a chain reaction has led to the emergence of new industries. The discoveries made at the turn of the twentieth century gave rise to the development of a whole new sector, the food-industry. Until then the subsequent steps from agricultural production to the market and finally to the customers' table were short and simple. With increased knowledge about fractionalization, preservation and transformation of foodstuffs, several steps were added to the foodstuffs-chain, which was the beginning of the lengthening and differentiation of the chain in food-production. Basically, similar kinds of processes have taken place in the chemical industry, albeit somewhat later. The joint results in these field have layed the foundations for modern biotech research, especially in agriculture and the food-industry, and therefore we will start our discussion in these two, related fields.

The time-period that we discuss in this chapter, starts with the early developments in the two sectors, roughly to World War II. The war has been a rupture in developments, both for telecommunication and biotech-related sectors. Ambitious plans, often set in motion in the nineteen thirties had to be cancelled and the devastating effects of the war were strongly felt. The post-war reconstruction was on the one hand a reconstruction of the social and societal relations of the nineteen-thirties, but on the other hand it allowed for new influences and thus marked an era of renewed openness towards the surrounding world. We will discuss these developments in more detail in the chapters still to come.

This chapter first provides a 'guided tour' along major events in telecom, and in the sectors which have layed the foundations for later biotech research. In this chapter we follow history, more or less, in a chronological sense. However, in the text we have reserved some room to interpret the historical meaning of specific events, as they have set the path for future developments. Here we have indented the text and used italics to differentiate these sections from the more descriptive parts.

In the final, concluding section we will highlight some interesting developments which are to be seen as 'structuring events' for the later development of the telecom and biotech-sector.

4.2 Telecommunication

4.2.1 The introduction of telegraphy

The history of Dutch telecommunication[1] started in 1839 as a private initiative. The industrialist Eduard Wenckebach, manufacturer of fine mechanics and apparatus, was the first to make a request to the Minister of the Interior to build an experimental telegraph-line along the railroad-track from Amsterdam to Haarlem, a distance of almost 19 kilometres. At the same time the possibilities of telegraphy were recognised in scientific circles and professor Vorsselman de Heer also made a request to the Minister to install a line along the track Amsterdam - Arnhem, a distance of some 102 kilometres.

However, none of the two received an answer. The minister kept the requests in the bottom-drawer of his desk until an officer of the military, the lieutenant-colonel van Panhuys, filed a very positive report about the future possibilities of telegraphy. On his instigation the minister commissioned a committee to study the possibilities, desirability and costs of the railroad-telegraph and in 1845 the actual works started on the Amsterdam-Haarlem line.

The first line was built parallel to the railroad-section between Amsterdam and Haarlem. This was efficient in several aspects. The railroad section was the most efficient and shortest route between the two places and the land, which was needed for telegraph-posts, was owned by the railroad company. But it was also clear that the railroad company could benefit from the telegraph line. It would provide easy communication between railway stations. Given these advantages, the railroad company was also willing to finance the project. There were mutual interests between the telegraph initiatives and the railroad-company, and thus, between the world of transport and communication.

The construction of the first Amsterdam - Haarlem telephone line was done under the responsibility of the Hollandsche IJzeren Spoorweg Maatschappij[2] (HIJSM), and the industrialist Wenckebach was appointed manager of this project. Wenckebach was also the supplier of equipment. Even though the initial tests were rather disappointing, a decision was taken to extend the Amsterdam-Haarlem line to The Hague and Rotterdam. Initially the telegraph line was solely reserved for railroad messages. However, the HIJSM saw commercial opportunities and requested the Minister permission to open the line for public use, however, without receiving an answer.

The attitude of government at that time was reserved, even with a clear a sense of mistrust. This is understandable, because the country's financial situation was precarious at that time, which made government reluctant to invest in large-scale and capital-intensive projects. A further reason for mistrust was that telegraphy could possibly develop into a competitor for the State Postal-Service which was only in its infancy. But next to economical arguments there was also a political sense of mistrust because government feared that the public could use the telegraph in case of political turmoil.

This reserved attitude towards telecommunication changed under the threat of foreign competition. English companies had requested permission to demonstrate the advantages of telegraphy, yet government feared that Dutch industry would lag behind, if not a more active policy towards telecommunication was developed. Shortly after government granted concessions to the HIJSM, and Wenckebach started to extend the telegraph-line to other cities.

Compared to the surrounding countries, the Dutch telegraph network was rather late to develop and comparatively small, reason for a government commission to plead for a further extension of the network to abolish the 'state of isolation and exception'. In sight of the sheer benefits for trade, industry, railroads, administration, police, state-safety and defence, a committee recommended state-exploitation of a telegraph network. State-exploitation was preferred over private exploitation, because private

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[1] In the historical overview of telegraphy we build extensively on the work of De Wit, 1994, pp 273 - 298

[2] *'Hollandsche IJzeren Spoorweg Maatschappij*', literally translated as: *'Dutch Iron Railroad Company'*

exploitation would only concentrate on beneficial lines and would possibly neglect loss making regions. In line with this report the Telegraph Act passed in 1852 and remained virtually unchanged until 1904.

The decision to opt for state-exploitation was partly based on the report mentioned above, but also on international interests. In 1851, even before government had decided for state-exploitation, the Netherlands had already started to participate in the Austrian-German Telegraph Society[3] in which Prussia, Austria, Bavaria and Saxony already participated. Prussia was only willing to connect the Dutch telegraph network to the international network, on the precondition that the Dutch network was exploited by the state.

The importance of international cooperation was furthermore obvious from the choice of technology. In the first years of telegraphy there were several, more or less competing systems. Even an original Dutch design was taken into consideration. However, the Netherlands decided to opt for the Morse-set, because it was accepted by the Austrian-German Telegraph Society as the ruling standard.

By that time the Netherlands lacked a true telecommunication industry and therefor the elements for the network were ordered from abroad: water-cables in the UK, iron wire and insulators in Belgium, copper-wire in Germany. Telegraph equipment was also ordered in Germany at Siemens & Halske, who produced equipment based on Morse's technology. The telegraph network developed most prosperously and by the 1870's it had developed into a large-scale technical system, with a nation-wide coverage and international connections.

The telecommunication sector has provided us with some interesting examples of path-dependence and increasing returns. The process in which the Morse telegraph has become the standard in telegraphy is a clear example of an increasing-returns process.
In the early days of telegraphy, several technologies were used to transmit a telegraph message.

Most of these technologies were based on electromagnetic induction technology, mainly building on the discoveries of Michael Faraday. These technologies entailed several systems whereby magnetised needles were set into motion by electric impulses. In some of these systems the message was communicated through a certain sequence of motions of the needle. An 'A' for instance, was one deflection of the needle to the right, while a 'B' was formed by one deflection to the right and one to the left, end so on and so forth. In other systems the needle could point at a particular letter of the alphabet on a dial.

Yet, Samuel Morse had developed totally different design. He developed a system of codes, whereby each letter was represented by a combination of long and short pulses. The telegraph operator at the sending end of the line used a code-key to transform a written message into code. At the receiving end of the line there was a machine that could print the letter-code in a tape of paper. The operator was able to read the code and translate the message back into written text.

Even though the first systems in the Netherlands were based on Faraday's needle-telegraph technology, the Morse-system finally became the standard in telegraphy. What strongly promoted the preference for Morse-technology was the desire to be connected to the Austrian-German telegraph network. This network was already operated by Morse-based equipment and it was an obvious decision in 1851 to adapt this as the leading technology and to install Morse-based equipment. In 1852, when the connection was made with Belgium, the Dutch negotiated that the system would only use Morse-equipment. Thus, the larger the number of users of a particular technology, the greater the chance that this particular technology will develop into the standard-technology in a given sector. In this process of increasing returns, other technologies were soon marginalised.

Box 13 *Path dependence and the choice of the telegraph standard*

4.2.2 The introduction of telephony

The introduction of the telephone was much of a triple jump. It developed along a different trajectory than telegraphy. Private telephony was already functioning in the small-scale setting of hotels,

3 Deutsch-Österreichischer Telegrafenverein

hospitals and factories, before it was used in the public network. The future function of telephony was initially largely underestimated by the State Telegraph Service. This office did not comprehend the future prospects of telephony as a means to communicate messages between two individual subscribers. It only saw telephony as an additional service for the already existing telegraph service, as a means of giving an order for a telegram to the telegraph office from a certain distance, instead of going to the telegraph office. In this line of reasoning it arranged the first experiments in telegraphy in 1877. The first experimental line was built, using the facilities of the existing telegraph net. A new set of air lines was attached next to telegraph lines and the telephone itself was installed in the telegraph-room of a telegraph station. Not surprisingly, the first results were rather poor. This was partly due to technical reasons, because the new telephone-line was induced by the parallel telegraph-lines. But the poor result was also the result of the setup of the experiment. It did not cross the mind of telegraph-technicians and operators to see the telephone as a new, independent service to the public. They could only imagine the telephone as another way to deliver a telegram-text to the telegraph-station, and it was therefor that the experimental telephone was installed in the noisy telegraph-room. It turned out that it was virtually impossible to understand the message, firstly because the induction in the telegraph lines disturbed to the telephone-signal, and secondly because the poor quality of speech could hardly be understood in the noisy telegraph-room. Using the telephone under these circumstances could easily jeopardise the accuracy of the State Telegraph-Services and the telephone was initially abandoned from public services. This was a clear example how the State Telegraph Service initially suffered from a 'lock-in' of an existing technology, and thus made room for the initiatives of local entrepreneurs.

The State Telegraph Service did not recognise the future for telephony as a public service, however it was a promising technology for the technical service department of the State Telegraph Company to be used in its field work, and, with good results. It also served a useful purpose in the setup of a temporary communication line between construction works of the State Telegraph Service on the West Frisian Islands. As a result a request was made by the island dwellers to open the service to the public and to extend the telephone line to other (remote) areas. These actions have put pressure on the State Telegraph Service and in 1881 the telephone-services were slowly integrated in the Telegraph Act, initially as an extension of telegraph services. By that time no single subscriber, but only the telegraph-stations were connected to the state telegraph/telephone network. The telephone was exclusively used to give up a telegram.

The close relation between telegraph and telephone would have made state-exploitation of the telephone most obvious, but this did not happen. The initial exploitation of local telephone networks was left in private hands. This reflected the situation in the USA, where private exploitation was most successful. Moreover, the telephone had only a limited -local-reach and was not seen as a common interest for the general public. Furthermore, government was also very reluctant to start a new service, because the results of the telegraph system were still loss-making. Thus, next to state-exploitation of the telephone/telegraph network, several concession-rights were granted to private companies to start local networks (De Wit, 1994, pp. 291-98; Hogesteeger, 1981, pp. 161-176; Hogesteeger, 1989).

The Nederlandsche Bell Telefoon Maatschappij (NBTM), was the first to recognise the potential of telephony for private customers and it opened a private network in Amsterdam, starting with 49 subscribers. Networks in Rotterdam and Arnhem soon opened similar services in 1882, networks in Utrecht, Haarlem and Dordrecht in 1883. By 1884 nineteen networks were operational, most of them exploited by entrepreneurs like Ribbink and Co, the Enschedesche Telefoon Maatschappij, the Alkmaarsche Telefoon- en Goederenbesteldienst owned by Jan Pot, and J.W. Kayser.

The reach of the telephone services was extended considerably when government granted the NBTM concession to connect the Amsterdam local network with the local telephone networks of Zaandam and Haarlem. By 1890, most of the private local networks were mutually connected. International connections soon followed, albeit later than in most other European countries. A connection to the Belgium network was made in 1895, and a year later with Germany. However, It took until 1922 before a telephone connection with the UK was established (Schuilinga, 1981, pp. 17-9).

Local authorities have recognised the potential of telephony much earlier than the state-government. The Amsterdam municipality was keen to use the momentum at the ending of the NBTM concession to take over the local network. It started ambitious plans to modernise and to extend the network. Similar action was taken by other municipalities. At the turn of the century most local networks were brought under the responsibility of local authorities. The responsibility for the trunk-lines was taken over by the State in 1897 and organised in the Rijkstelefoondienst (State Telephone Service). The 1904 Telegraph and Telephone Act, which replaced the 1852 Telegraph Act, gave the State a more active role in the exploitation of the telephone system. It allowed the State Telephone Service to connect individual subscribers outside the concession areas. From 1906 onwards the State started to exploit local networks and gradually extended its reach by taking over the existing local networks from local proprietors, whether private owners (industrialists) as well as public owners (municipalities). In 1916 it took over all the local networks of the NBTM and in 1919 those of Ribbink, van Bork and Co. By 1927 all local telephone networks, except those of Amsterdam, Rotterdam and The Hague, were acquired by the State Telephone Service. Next to the fact that the State Telegraph Service did not have the capital to take over these three networks, there also was no technological need to do so. The Amsterdam, Rotterdam and The Hague networks were in fact the frontrunners in modernisation. Rather than taking over the deteriorated Bell networks, these three cities had preferred to build completely new networks. These networks were also the first to install the first semi-automatic switchboard in Amsterdam in 1911. It was Amsterdam network again to install the first fully-automated switchboard in 1922. Yet, Rotterdam and The Hague soon followed (Holcombe, 1911, cited in Noam, 1992). The State Telephone Service only started to modernise the network in 1920. Air-lines were replaced by ground cables and several new international connections were made, which also led to the first amplification of long distance lines. Automation of the switching systems became an issue in the mid nineteen twenties and, following the decision of the three big cities, the State Telephone Service started to install automated system.

	Offices	**Number capacity**
Destroyed	62	30,700
Stolen	6	8,000
Dismantled	17	1,900
Partly dismantled	15	11,350
Damaged	110	32,500
Total	210	84.450

Table 23 *Damaged and destroyed switching nodes*
Source: Annual report PTT 1945/46

Despite modernisation of the network and the automation of several newly installed switchboards by the State Telegraph Service, the underlying policy could be characterised as reactions by incident and accident. Telephony had developed into a ‘mature’ service, next to telegraphy, but a coordinated ‘master-plan’ for its development was still lacking in the mid-nineteen twenties. In 1928 the telephone and telegraph service was reorganised and accepted the international common name PTT (Dienst der Posterijen, Telegrafie en Telefonie) and the new organisation launched an ambitious plan. A totally new design was made for the network lay-out, for the automation of district-offices and trunk-offices, for number-systems and tariffs, etc. The decision to automate the local networks was made in 1932 and in 1937 the decision followed to automate the entire telephone system within the next fifteen years (van Hilten, 1981, pp. 45-80). Siemens & Halske was chosen as the preferred supplier and in turn for this large order a licence was granted to Dutch industry to produce a standard telephone set. This marked the introduction of a uniform telephone-set in the Dutch telecommunication system.(Tours, 1981, pp. 33-44)

A good deal of the ambitious plans was under construction when World War II threw a spanner in the works. The immediate result was that the Netherlands was cut-off from all international connections, except the connections with Germany.

Despite the outbreak of the war, the construction-works initially continued, even though productivity gradually decreased from 1940 onwards. In 1943 a large housing project for PTT was finished, but already before that date restrictions were introduced for the use of the telephone system. ‘Normal’ transmission was virtually impossible from 1944 onwards. Later that year a process of destruction and theft started, which finally resulted in the break-down of two/third of the total communication system (Schuilinga, 1981).

4.2.3 Provision of equipment in telecommunication

The initial telegraph system started in the mid-ninetieth century with equipment built in Edouard Wenckebach's workshop. By that time equipment was not standardised and several technologies were mutually competing. By 1852 the Morse apparatus was the most obvious standard in telegraphy and recognised as such by the Austrian-German Telegraph Society. Given the eagerness to participate in this international network, the State Telegraph Service accepted the Morse-set as its standard and ordered its first sixteen signalling devices at Siemens & Halske, which was the preferred supplier of the Austrian-German Telegraph Society. It goes without saying that Siemens and Halske was also the preferred supplier for further extensions of the system (de Wit, 1994). The first experiments in telephony by the State Telegraph Service were also done with equipment purchased from Siemens & Halske.

It is hard to reconstruct how a preference for a specific supplier has come into being. In the State Telegraph Service case the engineers that were responsible for the purchase of equipment in telegraphy have been shopping around. Cables from England, insulators from Belgium, copper-wire from Germany. Their preference for purchasing telegraph switching equipment from Siemens & Halske might have been influenced by mutual backgrounds. The two Dutch engineers -van der Kun and Conrad- were trained in the military, and so was Werner Siemens, who had built the main telegraph lines in Germany. Another possible reason which might have re-enforced the close relations between the State Telegraph Service and Siemens & Halske is the patent regime in Germany and the Netherlands. This was especially relevant in telephony, because the Bell telephone was not patented in Germany. This provided an excellent opportunity for Siemens & Halske to copy and improve the Bell-telephone. In the Netherlands the patent-law was temporarily suspended as off 1869 (de Wit, 1994)

Box 14 *PTT's preference for Siemens' equipment*

The private-owned networks started with equipment purchased from various suppliers. The NBTM for instance purchased its first switchboards from the Gilliland Electric Manufacturing Company, a concession-holder of the Bell Telephone Company. These switch-boards were not only installed in Amsterdam, but in all the bigger Dutch local networks where the NBTM held a concession. Other private networks chose for switching equipment supplied by the Western Electric Company (WEC) or L.M. Ericsson. With the extension and modernisation of the Amsterdam system in 1896 another supplier entered the stage: Stock & Co from Berlin. By that time the Bell Telephone Manufacturing Company (BTMC) founded its first European subsidiary in Antwerp and also became an important supplier for the Dutch telecommunication system. The private networks' choice of suppliers has caused a scattered pattern of suppliers over the country, a pattern which largely remained in place into the nineteen sixties. Only then Dutch PTT decided to replace alle switching equipment by Philips and Ericsson equipment. An earlier decision in 1937 to choose Siemens & Halske as the preferred supplier of the Dutch telephone network was jeopardised by World War II.

With the introduction of the automatic Strowger switch a new era in switching started. Siemens held the European patents for this technology and installed its first automated switchboard in Amsterdam. The results, however, were not entirely supportive, reason for the municipality of The Hague to choose the rotary-system of the Western Electric Company and stick to its initial local supplier. The rotary system was also used in the switching systems of the BTMC, as well as in the Ericsson automated switchboard. As a result, the Dutch telephone-system had a variety of switching systems by the mid-nineteen twenties. The larger cities had already an automated switchboard, because these cities could afford the large investments needed. It turned out to be a beneficial decision. Telephony had proven to be a good source of income.

As a preparation for the automation of the smaller networks the State Telephone Service had extensively studied the Bavarian telecommunication system, and made an experimental setup in the Arnhem network using Siemens & Halske's equipment, and this experiment turned out to be a great success. With the 1937 decision to automate the entire telephone network, PTT also decided for Siemens & Halske as the preferred supplier (van Hilten, 1981).

> Most telephone-operators have displayed a remarkable loyalty to their suppliers. The initially private owned companies purchased equipment from a range of suppliers. Extensions of the system were usually purchased from the same supplier. This is not very surprising because the life-span of switching equipment was rather long, the investments were high, and the costs of switching to a new supplier were also expected to be high. Thus, when the State Telegraph Service, which later developed into Dutch PTT, started to take over the private companies, it usually left equipment in place, unless it was clearly functioning below par. The modernisation of the network, especially the automation of the switching functions, provided a good opportunity to get rid of all the different systems that were in use in the early nineteen thirties, and to change to Siemens & Halske switching equipment. PTT, evolving from the State Telegraph Service, had a clear preference Siemens & Halske as suppliers. This preference was already developed in the early days of telegraphy in the mid nineteen fifties. Also, in the first experiments in telephony it used Siemens & Halske equipment and it has kept that preference ever since. The decision to automate the switching function in the mid nineteen thirties and PTT's leading position as the most important national operator provided the opportunity to replace all existing systems by Siemens & Halske automated switching systems. However, World War II threw a spanner in the works. Being a German firm, Siemens & Halske was no longer welcome.
>
> Repair of the damaged system was basically an attempt to prolong the pre-war supplier-operator relation. Siemens' role was taken over by Philips, but the local networks which purchased equipment from other suppliers, remained loyal to their initial suppliers. Once a preference for Ericsson-equipment, always a preference for Ericsson, and the same holds for other suppliers. The reason why operators stick to their initial supplier is that the costs of change are much higher than just the price for equipment. Operators and technicians have to be re-educated. The characteristics of new switching equipment may have been well codified, but the way how the switch-board operates best in a given network is usually of a much more tacit kind of nature. Technicians usually know the ins-and-outs of the network and are able to fine-tune the network to the characteristics of all the elements in use. Thus, the change from one system to another and from one supplier to another was extremely risky because the costs of such an operation could be much higher than the benefits of change.

In end-user equipment there has always been a variety of systems. In the mid nineteen thirties, when PTT decided to give Siemens & Halske its 'preferred supplier status' it received the Siemens licenced for end-user equipment in return and the Dutch Heemaf Company started the production of telephone sets. By 1940, approximatel y 50 % of the all the Dutch telephone sets was produced by Heemaf, using German technology.

Transmission equipment was initially also purchased from abroad. However, as soon as the telecommunication networks decided to switch from air-lines to ground cables in the nineteen twenties, a genuine Dutch industry started. This was induced by two factors. First, World War I had demonstrated the vulnerability of the country's economy. Overseas trade was difficult, if not totally impossible. Telecommunication equipment, that was ordered before the war, was only delivered after the war. The Netherlands felt that its dependence from foreign suppliers was a threat for its economical independency and the foundation of an independent telecommunication industry was welcomed. Second, the Netherlands already had well-developed basic skills in cable production. Rope making has been an important skill in shipping and waterworks for many ages and the Netherlands had an extensive industry of rope yards. The technology to produce telephone cables has a lot of similarities with the traditional rope technologies in hemp or steel and still today there are several Dutch companies like Draka, Pope, the TKF and NKF , which have still strong names in the cable industry, or even belong to the top three European companies (De Jong and Tours, 1981, pp. 129-61).

An interesting feature in transmission technology was the so-called 'pupinisation' of cables, especially because the reach of the decisions made in the 1920 was still felt into the nineteen seventies and even later. Until the nineteen twenties, most connections were made using air-lines, usually galvanised iron or copper cables hanging on wooden telegraph-posts. This was a rather vulnerable system and ground cables were thought to be a better solution. However, ground-cables had some marked technological differences with air lines. The electrical resistance in air-lines for instance, is much lower, and capacity as well as self-induction is more or less balanced. That is not the case in ground-cables. Especially the higher frequencies are lost over distance.

By that time it was already known that Pupin coils -named after the inventor- placed at regular distances in the cable could improve self-induction, but the theoretical knowledge about this phenomenon was only limited. Finding the right balance was rather a matter of trial and error, than of scientific efforts. No other measurement equipment but the human ear could be used at that time. However, the consequences of the decisions then made, had far reaching implications for the future. The Dutch approach towards pupinisation has resulted in a cable impedance of 800 ohm, while most of the other European countries had an impedance of 600 ohm. In general this was not much of a problem, because differences between national networks could relatively easy be filtered out or otherwise adjusted. But the difference was especially felt in end-user equipment which was especially adjusted to meet the 800 ohm national norms. This made Dutch end-user equipment incompatible with those of other countries, even with those of the neighbouring countries, Germany and Belgium (ibid., pp. 136-9). It follows that the Dutch telephone industry solely produced for the Dutch market and had no export-orientation whatsoever.

This national orientation had far reaching consequences, especially in end-user equipment. The low quality in voice communication, which changed every voice into 'Donald Duck-like' sounds, could be tackled along several routes. Most national PTT's opted for an improvement of the loudness of the signal, but Dutch PTT took a different approach. It opted for improvement of audibility, using the full capacity of the Dutch System's characteristics. Several incremental innovations have pushed developments towards increasing sophistication in audibility, but with each innovation the system differentiated itself more from systems in adjacent countries. Thus, the Dutch system developed into a high-quality system, but incompatible with other countries. A series of small, incremental innovation and their application in the network have led to a range of subsequent steps, which could hardly be reversed without high costs. Only major developments, such as the digitalisation of the network in the nineteen eighties could erase the differences between country-specific systems.

4.2.4 Niches in Dutch telecommunication

A special niche in Dutch telecommunication was radio-communication, especially long distance transmission. This must be understood against the back-ground of the extensive Dutch trade-interest with its colonies in the East Indian Archipelago and the Caribbean. At the beginning of the twentieth century it sought connection with the colonies, using British sea-cables. However, as soon as the UK was involved in World War I, the sea-lines were strategically importance for warfare, and 'London' gave only low priority to trade-messages.

An alternative was sought in radio-communication. However, it took until 1923 before PTT opened its first long-wave telegraph transmission service for the public. PTT engineers have invented, designed and build most of the equipment on their own. Initially they used long wave equipment, for which the first experiments started in 1917 with an attempt to transmit telegraph signals from Western Java to Europe. The experiments in radio transmission were at the edge of the known technologies. As so many engineers in other countries, the PTT engineers were exploring the boundaries of long wave transmission, because the results seemed to be most promising for long-distance communications. However, this technology was extremely expensive and budgets were only limited available. Yet, PTT engineers were intrigued by the results of radio-amateur using the ultra short wave in long-distance transmission. Key for the success of these experiments was not so much the capacity of the transmitter, but keen use of atmospheric circumstances. The low costs of equipment made experiments attractive and PTT researchers and their East Indian colleagues started a series of experiments in the ultra-short wave area and with most promising results. Ultra-short waves could be propagated in the ionosphere, thus bridging extreme large distances. The experiments resulted in the opening of a short-wave telegraph service in 1925. It took another two years before the first telephone call could take placed. This achievement was truly remarkable, because it was the longest direct connection on the globe (12,000 kilometres) using single-sideband technology in the short wave area. Soon after the establishment of the The Hague - Bandung connection, many other radio-connections were established (Visser, 1981, pp. 109-128). The Dutch success in the ultra short wave area was soon taken up by other countries and radio telephony remained relatively important until in 1956 a sea-cable between the UK and the USA made this service redundant for the public network.

Telegraphy was also important in ship-trading. However, war-circumstance had changed radio transmission equipment from a utility into a strategic good, and imports were restricted. It was in 1918 that a group of shipowners decided to start a Dutch industry: the Nederlandsche Seintoestellen Fabriek (NSF)[4], The NSF initially was able to produce relative simple radio-telegraphy equipment, but it lacked the capacity to produce components, as well as it had the capacity to make a next technological step in the development of radio equipment. It shifted its business and broadened its orientation to the production to a wider range of shipping equipment, such as compasses, but also to products outside the sector, such as bicycles. For innovation it needed a solid partner.

By that time Philips was its supplier of vacuum-tubes. Philips' core business was in light bulbs in the early nineteen, but in the advent of radio-communication it had extended its business to vacuum-tubes, which were at the heart of radio transmitters and receivers. This was a logic step because the production of light-bulbs and vacuum-tubes share much of the same technology. It is along this line that Philips got involved in telecommunication. The NSF held interesting properties for the Philips company for two reasons. First, it was an important buyer of components, and second, the NSF was already involved in radio-equipment for broadcasting purposes, and this was an interesting field for a further extension of Philips' business. Therefor Philips started to participate in the NSF and Anton Philips, who had a nose for business opportunities, became commissioner in 1923. Philips gradually took over the block of shares of the shipping companies, and from 1926 Philips had a final say in NSF. Even though Philips owned the NSF, it still used the name NSF. It extended production into three directions. It continued the production of communication equipment to be used in shipping, aviation and in the military. Then it extended production towards broadcasting equipment: large broadcasting transmitters and it specialised in wireless sets. (Heart of the activities was the NSF plant at Hilversum and the first broadcasting activities were organised at the NSF studio. Today, Hilversum still is the centre of the public radio and television broadcasting organisations) A third line of production was in fixed line transmission equipment, where the NSF/Philips combination developed into an important supplier of components. In 1933 it had already started the production of Pupin-coils, which were very successful at home and abroad. It also started to build amplifiers and multi-channel carrier-wave systems. NSF/Philips was also involved in cable-technology and the production of measurement equipment. Thus, NSF had specialised in transmission technology,

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[4] Nederlandsche Seintoestellen Fabriek, transl. Dutch Signal equipment Works

equipment and components, especially to be used in radio transmission and in network-development.

4.2.5 Structure of research and development activities

Fixed wire technology was basically provided off the shelf to the State Telegraph Service and the local networks. R&D was regarded to be the responsibility of the suppliers and there was virtually no Dutch industry to produce telecommunication equipment in the first decades of the twentieth century.

Radio communication however, was a different case. At the beginning of the twentieth century, radio equipment was still highly experimental, but it held great promises, especially because it could provide the opportunity to make long distance communication independent from intermediate (foreign) transmission stations. This was especially important for traffic with the colonies, and in international shipping. Thus, in 1919 the State Telegraph Service started the first experiments in the Bureau for Experiment, Research and Education. In 1925 the Radio Laboratory was founded as the operator's first research and development department. This laboratory has existed till 1946, when the radio lab was integrated in PTT's new Central Laboratory. PTT, which evolved from the reconstruction of the State Telegraph Service in 1928, had a good reputation in radio technology. Its radio lab was the first to develop and introduce single-sideband transmission in the ultra short wave range. Its service, however, was relatively small and thus, there was hardly any division of labour between research, development and operations.

The problems in fixed line telephony were of a completely different nature. The initial private structure of the telephone network had led to a variety of system and with it, to a variety of technological requirements. Connecting these different systems into one, comprehensive system was the great challenge for Dutch PTT, just like the extension of the overall-capacity of the system. Extension of the network was one strategy, but increasing the capacity of the network-structure was even more promising. PTT put up several experiments to increase the number of channels, through several modulation techniques.

In 1929, soon after the reorganisation of the State Telegraph Service into Dutch PTT, a decision was made to concentrate the research and development activities in one department and in 1931 the Laboratory for Telegraphy and Telephony started its activities. By 1937 it had 22 employees, among them four engineers.

The focus in research was strongly oriented toward transmission technology, both in radio and fixed line telecommunication. Both systems held close contacts with the national industry, especially NSF/Philips. However, even though the technologies in radio transmission and fixed line transmission had quite some similarities, these were separate worlds in PTT's research structure. The foundation of PTT's Central Laboratory in 1946 brought these two fields of research in one organisation, but the distance between the technologies remained the same, until a change of management lowered the barriers for cooperation.

The telecommunication network that came into being until World War II has clearly evolved from a patchwork of (initially private owned) local networks, with several distinct technological differences. Some of the differences were ruled out by the connection of local networks in the national trunk-network, and others by the connection to the international network. Yet, there has never been a general 'grand-design' for the telecommunication system. National and even local differences were rather the rule than the exception. This patch-work-like system demanded a constant adjustment and readjustment of local systems to meet the general demands of the national system.

In the period under review the Netherlands has developed a genuine telecommunication industry which was active in most of the telecommunication branches. However, there were no attempts to enter the field of switching. Foreign suppliers held strong positions in that field. The specialization pattern mainly concentrated around network technology, transmission and network management.

Attempts to improve the network's performance were initially fragmented, with local technicians mainly involved in local adjustments. At the reconstruction of the State Telegraph Service into PTT, these local activities were brought together in the T&T Lab. This laboratory specialised in a range of adaptive innovations, constantly on the move to get the best performance of the given network-setup. The organisation of innovation activities was a closed-shop approach, with only few links to industry or the world of science. Many adaptive solutions were developed as the result of in-house operations. Training and education of future technicians was also organised as in-house activities. Solutions were not so much sought in the cooperation with other organisations, but rather within the company. This was the case in fixed-line telecommunication, but also in the radio-telecommunication niche, in which Dutch PTT had such an excellent performance. In this latter field we also find a strong focus on in-company solutions, rather than in cooperation with others. Even the cooperation with Delft University in the field of propagation was only remotely developed. Most of the experiments were setup under PTT's own account. The reason was that much of the technology was still in its infancy or still to be discovered. The research efforts were largely a matter of trial and error. The few basic principles of propagation were rather well understood, but the variations provoked by geographical or atmospheric conditions were only on the verge of discovery. Many of the incremental innovations were developed in PTT's own workshop. Even crucial elements as the crystals for transmission equipment, were in-house products. In this latter field PTT was even a supplier for NSF/Philips

The same holds for the development of transmission equipment. The basic principles were well understood, but there was still so much to learn. Thus, PTT's innovative performance was mainly oriented towards an optimisation of methods, systems and equipment and a constant search for the best balance between the elements. Strength in these fields was rather sought within the organisation, through an organizational clustering of technicians and engineers, than in cooperation with other companies, or the use of external resources, like for instance cooperation with universities or with the foreign suppliers.

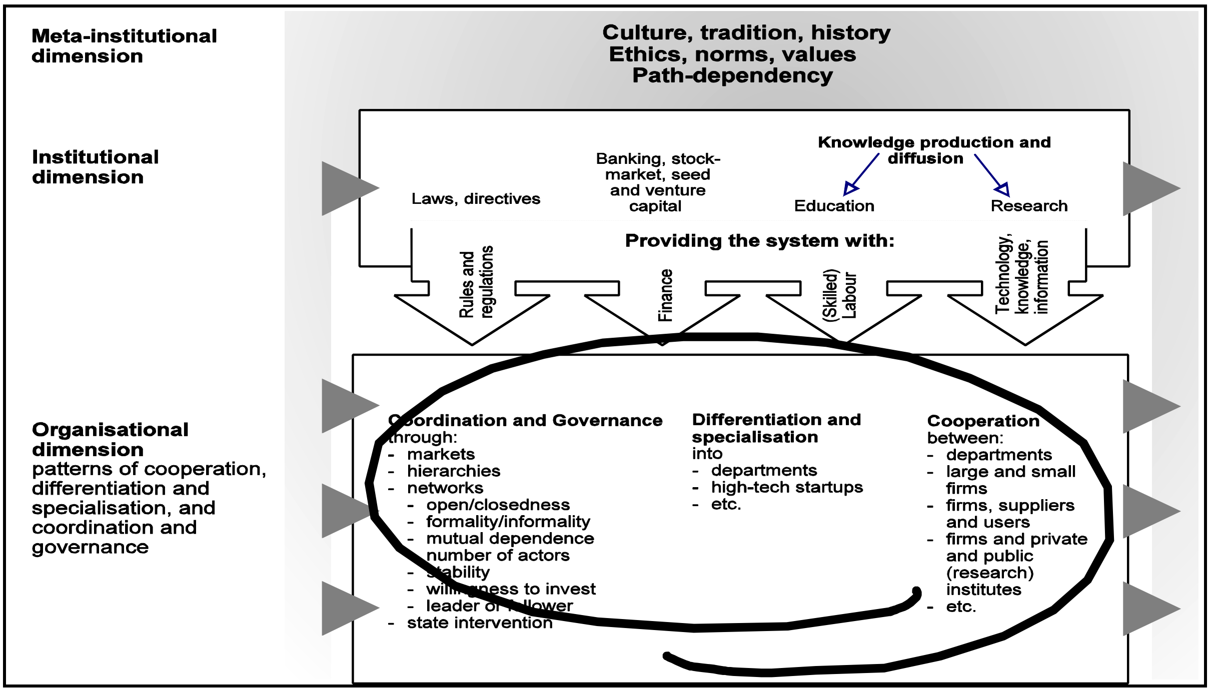

Figure 36 *Concentration of innovative activities in telecommunications*

If we now try to focus the centre of innovative activity in telecommunication in the model as it was presented in chapter 2, we see the strongest developments in the organizational dimensions. Departments which used to have separate activities were brought together, especially to benefit from mutual learning and to coordinate research-efforts. Knowledge in the telecommunications sector on how to optimise the network to its best performance was largely a matter of tacit knowledge in the pre-war years. Technicians did know all the peculiarities of a particular setup, but often they did not understand the underlaying scientific principles. Innovations were mostly small, adaptive innovations, usually developed in operations, or, in the case of radio-transmission, in experimental setups.

When PTT tried to coordinate its R&D efforts, it followed almost naturally that the major scope in activities was on network management. PTT technicians and engineers played no role whatsoever in the development of equipment. Their specialty concentrated in network-development and how to optimise equipment from different suppliers in one coherent system. This orientation in research has also dominated PTT's innovative activities in later years.

4.3 Biotechnology

Modern biotechnology is often regarded to be a toolbox of technologies, to be used in several industrial sectors as well as in several scientific disciplines. Especially in recent years many new tools have been added, or already existing tools have been combined to new tools. Each extension of the toolbox has led to new applications or to applications in new sectors. Modern biotechnology is not an unequivocal sector. Tracing back the roots of modern biotechnology is a difficult undertaking, because knowledge from so many disciplines and economical sectors is involved. For the Dutch case three sectors are especially relevant to be discussed in this context: the agricultural sector, the food-industry and the chemical/pharmaceutical sector.

> Innovations in one sector, may induce innovations in other, more or less related sectors. Canning for instance was an important innovation, and allowed a genuine food-industry to develop. In the slipstream of this development a whole new market appeared with excellent opportunities. Increasing demand and improved export-opportunities have boosted developments in agriculture. It also provided new opportunities, for instance for a large-scale meat industry to develop. Using meat-products and offal as raw material, several specialised industries developed. Thus, canning as a preservation technique, has induced innovations and strong economic developments in other sectors.

Box 16 *Innovations inducing innovations in adjacent fields*

The engine of economic development and innovativeness in all three sectors was especially fuelled in agriculture. A range of developments and innovations in this sector has induced developments in other industrial sectors, or has led to the emergence of whole new sectors which are depending on agricultural production. Gelatine-production for in-stance was developed in the slipstream of slaughterhouses, and used its offal as raw material for gelatine production. Animal fats were also the basic ingredient for the candle-industry, which was one of the founding industries for the chemical industry. The same holds for the pharmaceutical industry. Many drugs have been developed on the basis of by-products of the meat-industry. Organon, now part of AKZO/Nobel, used animal-organs for the production of medicine and drugs (e.g. pancreas for insulin).

An interesting example of the fusion between agriculture and industrial production is to be found as far back as the latter half of the nineteenth century in the province of Groningen. We will briefly highlight this early agro-industrial cluster to demonstrate how the combination of natural circumstances (waterways), scientific progress (e.g. the use of artificial fertilizer and steam engines), and traditional skills (metal works) have led to the emergence of a prosperous agro-industrial cluster, which stood at the cradle of several branches in the food and chemical industry.

The former peat district in the southern parts of the province was transected with an extensive system of canals, which were the result of peat-cutting. On the one hand these canals were meant to control soil hydrology, but on the other they were the infrastructures to ship the peat-bricks. The land, that remained after the peat-cutting, was a rare combination of sand and peat, and too poor for the production of corn. Farmers on the peat-lands were constantly on the search for the right combination of crops and fertilisation. It turned out that the former peat-land was best suited for the production of high-grade starch-potatoes. Farmers on these poor peat lands were very modern in the sense that they were very open to new methods, especially to the use of chemical manure, which was a relatively new product. Indeed they managed to increase production substantially through the use of chemical manure. On the waves of these developments, an agro-industrial cluster developed in the region during the latter half of the nineteenth century with 32 private owned factories for starch production. Initially rich farmers and industrialists took the initiative, but at the beginning of the twentieth century several cooperative initiatives followed. Between 1898 and 1916 twenty-two starch-factories were founded as farmers' co-operatives. An essential element of this emerging agro-industrial cluster was the system of waterways and canals. This infrastructure provided cheap transport opportunities for raw material, fuel and finished products. Also part of this industrial cluster was the presence of many machine factories and skilled metal-workers for the production of machines and their maintenance.

The conditions in the peat-district have helped to fuel the emergence of the straw-board industry. The northern heavy clay-lands were extremely well suited for the cultivation of corn. Contrary to the peat-lands with its poor soil conditions, the clay-lands were extremely rich and did not need any additional fertilisation. The main product was corn and its by-product 'straw' was often burned, because farmers had no use for it. Following initiatives in Ost Friesland (Germany), where several small strawboard factories were founded, rich farmers tried to set up similar kinds of factories in Groningen and Friesland. These first initiatives were not very successful. The first real success was a factory in Oude Pekela, named the 'Aastroom'[5], which managed to combined the best of natural circumstances (resources and infrastructure, with scientific knowledge. It was built close the source of raw material and fuels, it was connected by several waterways, it had the advantage of a well-developed machine industry, the water-quality was well suited for strawboard production, and it could especially profit from the technological skills of Ost Frisian paper-makers. It also profited from the increasing demand for strawboard. Innovations in transport had boosted developments in the packaging industry and strawboard was the best suited product (cf. Dendermonde, 1979). Thus, early in the twentieth century, the Groningen region had already a blossoming agro-industrial cluster.

If we make a giant leap in time, we find that production in the potato-industry has increased ever since. In 1903 the average production per hectare was 20 tons. In 1978 it had doubled to 40 tons and production is still increasing. Today, AVEBE is the leading company in Europe in the production of starch and starch derivates and it has a well developed research and development department. Its main field of concern is how to increase the proportion of starch in potatoes and to fight potato-diseases, like potato rot, canker, or mildew. This is a never-ending challenge. Plant-diseases are champions in adopting to changed circumstances. No wonder that AVEBE is constantly on the search for strong strains of potatoes, able to resist disease, fungus, insects, or natural circumstances like extreme drought of moistness. Most of the programs are based on natural selection systems, but AVEBE has also a program to modify the DNA structure in such a way that results can be predicted in advance, rather than through a process of trial and error.

The potato/starch industry is good illustration of a successful cluster in early agro-industrial development. However, it is certainly not the only one. We could also have picked other examples, like the sugar-cluster in the western part of Noord Brabant, based on the cultivation of sugar beets in the region. The cut-flower industry on the 'geest', the sandy soils behind the dunes could have served as another example. The latter cluster has developed into today's world biggest flower-auction. Or the gradual

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[5] The name 'Aastroom' is composed from two words: 'Aa' and 'stroom'.The Dutch word 'stroom' can be translated as stream or river. So Aastroom refers to the river Aa, and it clearly reflects the importance of the waterways for the success of the factory. Another indication for the importance of the waterways is in letter-heading of the companies' writing paper. Almost without exception they have a drawing in the letter heading, imagining the factory, with the waterway in front.

improvement of corn in the northern grain-belt. It is easy to make this list much longer, because the Netherlands has a well developed, highly specialised, and competitive agricultural sectors, with a large adjacent industrial sector. The Netherlands is on the leading edge in life-stock breeding, whether in cattle, pigs or poultry. The production in Dutch agricultural at the end of the twentieth century is still measured among the world's best. Milk-production per cow is unparalleled by any country. Also, the production per man-hour in arable farming, as well as in market gardening, is among the highest in the world. The Dutch agro-food cluster has an extensive meat-industry, with in its slipstream a range of related industries. It also has an extensive dairy-industry. Most of these sectors have well-developed research laboratories which have specialised in lactic acid bacteria and a broad range of fermentation technologies.

All in all the Netherlands has a broad palette of agriculture and related industries and in each field we find connections with modern biotechnology. Reason all the more to have a closer look at the early developments in agriculture, that reach beyond the above example of the starch-potato industry. We will especially focus on the setup of the institutional environment, that has been such a strong promoter of the application of scientific results in daily practice. After agriculture we will shift our angle to the food-industry and chemistry/pharmaceuticals.

4.3.1 Developments in agriculture[6]

The foundations for the remarkable economic performance of the Dutch were laid during the 'green revolution' which took place at the turn from the nineteenth to the twentieth century. The 'green revolution' was sparked by several important factors: firstly, there was an increased use of scientific knowledge in the production of agricultural products. With the introduction of Darwin's variation of animals and plants under domestication (1868), a new era in plant-reproduction started, which ultimately led to the production of one of the world's most productive wheat-strains. Similar processes can be observed in other farm crops, but also in animal- and cattle breeding. Secondly, there was an increased involvement of government in agricultural production and agricultural methods. Government was a strong promoter of the dissemination of agricultural knowledge to individual farmers. Next to the dissemination of agricultural innovations through the education system, it started an agricultural information service to advise individual farmers on the use of new methods and products, especially the use of artificial fertilizer (chemical manure). Thirdly, there was a wave of innovations in preservation technologies. Pasteur discovered that bacteria in milk could be made innocuous by heating (pasteurisation). Canning and freezing technologies were also discovered as food-preservation technologies. These innovations opened new opportunities, especially in the export of foodstuffs.

Trade and commerce

The impetus towards an increased agricultural production at the end of the nineteenth century was the regime of free trade on the one hand, and revolutionary developments in transports on the other. Most of the agricultural production until then, was aimed to fulfill the needs of the local environment, but under new conditions offered by transport (steamers) and preservation technologies, farmers could orient production towards export. This was not an entirely new attitude. It was basically a continuation of the open market-oriented attitude that had characterised Dutch farming since the late Middle Ages. After all, oversea's trade was the key to the successful Dutch Golden Age, which spanned more than a century from 1610 to 1740 (Arrighi, 1994, p.140)

Yet, better transport and an increasing demand for 'luxury goods', like meat, dairy products, sugar, vegetables and fruits, have stimulated production. This was not only the case in the Netherlands, but also in other countries and this has resulted in severe competition especially during the agricultural crisis in the latter half of the nineteenth century.

That the Dutch farmers could profit so much is partly due to the Dutch historical advantage in international trade, but also of the Dutch geographical conditions and position. The Netherlands has an extensive system of shipping routes which connects the country to major trade-nations abroad, as well as

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[6] This section extensively builds on the work of Bieleman, 2000, pp. 13 - 64 and 99 - 234.

with the economic strong ‘hinterland’, especially Germany. Inland shipping is well developed and a relative cheap way of transportation. The steam-engine has further boosted transport over water. Thus, when innovations in transport, packaging and conservation technologies appeared, the Netherlands could benefit to the utmost. This newly found market with its increasing demands opened new perspectives for agricultural production, and in its slipstream, for a broad cluster of related industrial products.

Organizational innovations

What furthermore has contributed to the development of such a strong economic cluster is the organisation of agricultural interests. Farmers started to organise their mutual interest in agricultural co-operatives. The first agricultural dairy co-operative started to operate in 1886. The climate was favourable and a range of agricultural co-operatives followed. Some of the co-operatives were formed when farmers tried to develop an offset against private factories. Others were instigated by government agencies. Especially the newly opened testing stations for practical research have been catalysts in the process of setting up agricultural co-operations. These test-sites were an independent institution to assess the quality of agricultural products, for instance, chemical manure. They also provided insight in the power relations between supplier-user relations, especially how some suppliers tried to swindle farmers with inferior products. Joining forces in co-operatives, negotiating contracts, obtaining discounts and quality control were strategies to restore the balance of power between farmers and suppliers. Cooperation in agricultural co-operatives, thus, gained momentum and an increasing number of farmers was willing to join forces. The success of the initial agricultural co-operations has boosted the foundation of even more, and more specialised co-operations. Some of these co-operatives were only limited to the purchase and provision of expensive tools, like threshing machines, seeders or fertilizer distributors. Others were organised to get the full reaps of agricultural products. The northern agricultural co-operatives had a strong appeal for farmers, and their success was used as an example for other farmers.

Success experience was also an important element for the setup of co-operatives in the southern provinces, but there was another factor that induced the emergence of agricultural co-operations. Sustained economic success organised in agricultural co-operations was a strategy for the emancipation of the predominantly Catholic farmers. That is why the co-operations in the Southern Netherlands were often instigated by clergymen. In the latter half of the nineteenth century the Catholics were still a neglected group. Thus, the setup of co-operations was also seen in the context of Catholic emancipation. Political parties, school-teachers and clergymen were strong promoters of this type of structures. Co-operations, thus, not just served an economic interest, but they also served a much broader societal and emancipatory purpose.

New societal midfield

This tight network of working together in co-operatives, in social clubs, in political parties and churches has provides the breeding ground for a new societal midfield, where public agencies, industry, the world of science, research and education, agricultural boards, banks (most notably the Raiffeisen and Boerenleenbank[7]), branch-organisations of farmers, consumers, housewives, youth-work and media were the main players. Their joint efforts have provided a conceptualisation of the future. This concept had a strong normative impact and the new societal midfield developed a zest for innovativeness, novelty and progress. The willingness to participate in far reaching programmes, like for instance land-reform programmes, was largely the result of this joint effort. The Dutch farmer developed a particular openness toward innovations, being its methods, equipment, quality, seeds, cattle, machinery, or organizational innovations like the co-operative. An important asset of the wave of modernisation in Dutch agriculture

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7 The Raiffeisen- and Boerenleenbank (agricultural loan bank) were both bank-co-operations. The model for this bank was developed by W.F. Raiffeisen (1818 - 1888), the mayor of the German town Heddesdorf. The difference between the Raiffeisen- and Boerenleenbank was the religious embeddedness. The membership of the Raiffeisenbank co-operation was reserved to Protestant farmers, while membership to the Boerenleenbank co-operation was reserved to Catholic farmers.

was the tightness of the system, its relative closeness and its high ability to fine-tune all the elements to the chords of modernisation and rationalisation.

Research, information and education: the OVO triptych

The reach of this system was such that all agricultural education activities were organised under the responsibility of the Ministry of Agriculture, without any interference of the Ministry of Education. Each level in agricultural education, whether secondary agricultural education or the agricultural university, was part of that very same system. Also, the elements of agricultural production, whether the provision of knowledge and funding, the system of education, the system of rules and regulations, but also the ‘softer’ elements like the organisation of social events were all organised within the same coherent institutional system. This provided the right conditions for the generation and effective dissemination of innovations at the turn of the nineteenth to the twentieth century, and for the development of a strong agricultural sector. The importance of the co-operatives is that they have been catalysts in the dissemination of important innovations like for instance, the use of artificial fertiliser, and modern feeds and fodder, like cattle-cake and silage.

The success of Dutch agriculture was furthermore based of an increased involvement of scientific knowledge in production methods. The key to success was in the successful combination of research, information and education-activities, all organised under the wings of the Ministry of agriculture. In Dutch literatures, this tight system is addressed as the ‘OVO-triptych’, whereby OVO stands for the Dutch acronym of <u>O</u>nderzoek (= research), <u>V</u>oorlichting (= information) and <u>O</u>nderwijs (= education).

Even before 1980 there was already an emerging system of agricultural lectures, organised by the director of the State Agricultural Winter School. These lectures were meant to disseminate new findings to farmers, for instance the use of artificial manure, water control or land consolidation programmes.
J. Kok, one of these early lecturers, reports on the foundation of the first agricultural society in 1860. As off 1878 several societies are founded to protect the interests of farmers. Each village had its own organisation, initially meant for the examination of young bulls, or the joint purchase of seeds, but soon these organisations were the pivots of agricultural life.

J. Kok, 1928

Box 17 *Emerging systems of agricultural education*

In 1890 the first agricultural advice service was founded with a ‘state-agricultural-teacher’ for each province. This service developed into a sizable network of agricultural experts who had an important function in the propagation of agricultural innovations. By 1940 the service had 150 employees, but in the latter half of the nineteen sixties the service has been extended to 1700 employees.

The agricultural winter-school was the centre of practical training for young farmers. It started its activity in 1893 and was the start of a broad system of primary, secondary and tertiary education in agriculture. The State agricultural school at Wageningen had already started in 1876 and developed into the Wageningen School of Agriculture as off 1918, and still later in the Wageningen Agricultural University, which is one of the leading agricultural universities in Europe. Its scientific production increased from several dozens of publication to several thousands, already around the turn of the century. The number of publications has doubled every 22 years since then.

4.3.2 Developments in the food industry

Agricultural production is the main input for the food industry. The increase of productivity of the agricultural production has -more or less- kept abreast with developments in the food-industry, but the variety of food-products has increased exponentially. Moreover, type, quality, appearance and origin of foodstuffs have changed considerably, especially during the twentieth century. However, we have to keep in mind that packed foodstuffs around 1890, was an exception, rather than the rule. Until that day, stallholders and grocers weighted products to the desired quantity and put the products in cans, pots or jars. In most of the foodstuffs of the 1890's the composing raw material was clearly recognisable. Porridge, for instance, was clearly made of milk and oats. In general, the steps from production to distribution, preparation and consumption were often local in nature and these steps were short. It was only a four-step sequence from farm, market, kitchen, an finally to the table. Margarine was one of the first composed foodstuff, and it was also the first to complicate and extend the foodstuff's chain. Before it was brought to the market, it had passed several stages of processing. Margarine was only a forerunner of change and soon many products followed.

The output of the agricultural sector was no longer directly send to the marketplace, but instead, it was used as an input for the food-industry to be processed in a range of new products. As an initial result, the number of stages in the foodstuffs chain has increased. This process of the lengthening the foodstuffs chain is still going on and still it is increasingly complicating, due to a range of technological innovations. In today's shops we will hardly find raw materials and ingredient. Even flour has been processed, whether to be used in pancakes, pizza, cake or pastry.

The most important innovations in the food industry were made in the field of preservation and hygiene technology, which allowed products to be transported and subsequently, to be processed somewhere else. Knowledge about nutritional value, vitamins and the composition of balanced diet was gradually generated and disseminated through a close cooperation between scientists, government, media and the education system. Wholesale and retail have played an important role in the dissemination of these new insights in food and foodstuffs to the customers. Housewives learned about the role of proteins, carbohydrate and fats, and nutrition became an issue in medical science.

The food industry is basically oriented towards four processes, which are depicted in the rows of the table below:

Targets	Process technology	Examples
Separation for the winning of valuable components	Fractionalization Breaking up in elements	Vegetable oil from soy-beans, sunflower; starch from potatoes, maize and wheat
Designing (bulk) components	Composition of (new) products	Manufacturing of pastas, spinning and extrusion of proteins; margarine
Increasing tenability	Preservation/stabilisation	Heat and cold treatment; drying
Acquiring the desired transformation	Transformation	Roasting coffee; baking processes, fermentation, enzyme-technology

Table 24 Processing technology from raw material
Source: Van Otterloo, 2000

As already mentioned, margarine was the frontrunner of a composed foodstuff, and it was followed by a wide variety of other foodstuffs. The quality of bread improved sharply when bakers could use purified bakers' yeast instead of beer-yeast. Also, the starch industry became a very important supplier of bakers' ingredients with products like sago, cornflour, custard and glucose-syrup. Also chocolate, milk-powder, fruit-syrup, jam, marmalade and vegetable oils and fats entered the market. The lengthening of the foodstuff chain has also led to a range of new products. The Netherlands already had an extensive industry of traditional oil-crushers, which were especially meant for the crushing and pressing of edible oils. Cattle-cake used to be just a by-product of this branch of industry. However, with the extension of life-stock farming, and the increased knowledge about nutrition value, a large-scale food and fodder industry developed from this traditional branch. Moreover, these industries have played an important role; not only in the dissemination of knowledge into industry, but also in the provision of capital for innovations and modernisations.

Pasteur's innovation (pasteurisation of foodstuffs), has had a strong impact on the Dutch food-industry, especially for the meat-industry. Preservation and canning technologies allowed for a totally new structure in the meat-processing industry. Until then, meat was transported as life-stock and then slaughtered at the place of destinations. This was a risky undertaking. Life-stock aboard of ships was vulnerable to disease, and unpredictable in case of storms. It was no exception when the quality of life stock sharply decreased during transportation. After the innovations in preservation and canning the structure of that particular chain changed. Life-stock was slaughtered in the Netherlands, canned or frozen and then transported to the destination. What is more, frozen or canned meat was much easier to store than life-stock. In the slipstream of these innovations several new industries came to blossom. The meat-industry developed with a range of slaughter-houses, cold-store warehouses, canning and packaging industries. But also a range of new industries appeared as strong niche-players. These industries specialised in the processing of by-products of the meat-industry, such as factories for bone-meal, blood-meal, gelatine, glue, etc.

Dutch households did not have a tradition in jam making. Pioneer in this branch was an industrialist in vinegar, who occasionally travelled to the UK, where he met this lively tradition of home-made jams and marmalades. After several years of experiments he started his own production, which was not so easy because the availability of sugar was rather low and, moreover, sugar was an excisable good.

The Dutch jam industry could develop most prosperously. Firstly, the product was welcomed on the market and secondly, Dutch producers did not have to fear British competition, because English goods were banned due to the South African Boer Wars and this particular situation gave the infant Dutch jam-industry a strong foothold in the Dutch market.

Box 18 *Introducing new technologies: jam-making*

Preservation technologies and food-processing technology were also the keys to success in the vegetable and fruit-industry. The number of products suited for export-purposes increased and allowed for an extension of the trade fleet, which in return helped to increase demand. This complex of developments stimulated exports-trade, especially to and from the colonies. The canning of food-products was initially an experiment to be used in the military, but as soon as the technology has proven its reliability, it was followed by the regular market soon.

Yet, there was also a dark side on the booming developments in the food-industry. The risk of forgery was a real threat for these relative new industries. It was relatively easy to cheat with products like butter, margarine and milk. Dutch butter had a bad reputation and this seriously threatened the Dutch export position. This was not only felt in butter, but also in adjacent product-groups. Given this threat, government, in close collaboration with science and industry started an ambitious plan to set up a system of public and semi-public control laboratories. A whole new knowledge infrastructure was built for the dairy industry, with professional journals, associations, courses, schools and research stations. Dairy consultants came to the farms to inform and educate farmers on new methods using a range of new instruction books. The efforts of industry, science and government got strongly intertwined in this infrastructure. This system rather parallelled the OVO-triptych that we already discussed in previous sections. The trend to involve independent quality control in the food production chain became an important warranty for export trade. The system provided a seal of quality for Dutch dairy products. Similar research centres were founded in other sectors of the food-industry. Organic-chemical knowledge, including the work of independent research laboratories was started in the corn and grain sector, in flour and bread industries, in the margarine industry, in breweries and in the yeast production industry. A network of private laboratories was erected to research the quality of public goods like water, but also for foodstuffs like cheese, milk, butter and meat. This tight system of cooperation in research and quality control has laid the basement for the prosperous development of the Dutch food-industry. Each sector had its own dynamism, but it was also pushed forward by innovations in agriculture, and increasing demand for new products. Public and semi quality control was an important regulatory and organizational innovation. These laboratories cherished their position of independence, but at the same time they were closely intertwined in the network that also entailed R&D, training and regulatory activities.

4.3.3 Developments in chemistry and pharmacology

The Dutch chemical industry of the late nineteenth century has profited from the close cooperation with the Delft school of polytechnics (from 1905 the Delft Technological University). However, most of the technologies in the initial phase of the chemical industry were based on developments in Germany, the

UK and France, and closely linked to developments in agriculture. The Dutch chemical industry had a remarkable multi-faced character, but it lacked the scale to compete with the large German firms like BASF, IG Farben, Hoechst and Bayer.

The growth of knowledge intensity in the initial phase of the chemical industry went through three stages: The first phase (1895 - 1914) started when industry started to recruit 'technologists'. In this period some firms even started their own research activities. World War I marked the beginning of the second phase with an increased cooperation between industry, the Delft School for Technology and other universities. During the Interbellum period a third phase took off when industry started to develop an in-house research capacity (Homburg, Rip and Small, 2000, pp. 298-315)

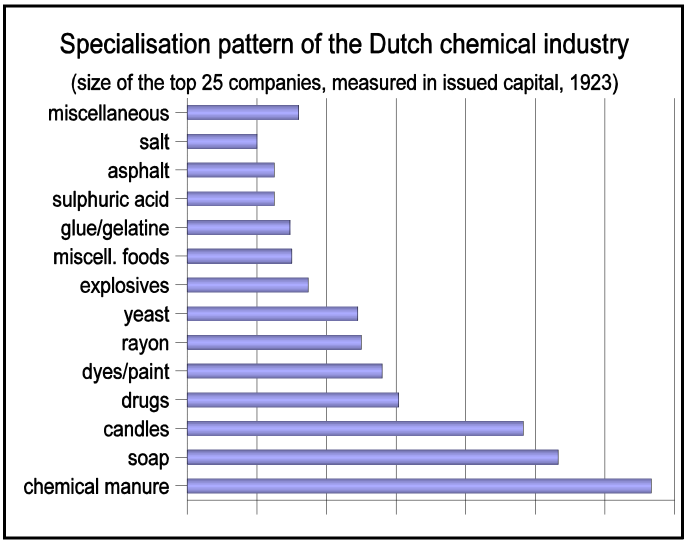

Figure 37 *Specialization pattern of the 25 larges Dutch chemical public limited companies, measured by the amount of issued capital in 1923*
source: Van Nierop & Baak

The Netherlands neutral position during World War I, has severely hampered the import of chemicals. Dutch chemical industries strongly depended on German imports of raw materials, but imports had fallen from 417,000 tons in 1913, to 93,000 tons in 1915 (CW, 1916; Woltereck, 1927). The war provided the fertile grounds and the right conditions to set up cooperation between chemical industries, a process which was strongly promoted by government. Government also played an active role in the distribution of goods and in the settlement of prices. In this atmosphere it was recognised that the chemical industry had some shared interests, reaching beyond the differences of the various production lines. In 1918 the chemical industries organised the Vereeniging van de Nederlandsche Chemische Industrie[8] (VCNI), a branch organisation that soon developed into the mouthpiece of the chemical industry. Mergers and take-overs during World War I have led to a concentration of chemical companies. Each market-segment was dominated by one or two leading companies. This structure basically remained intact for almost than 50 years. Only in the nineteen sixties a new wave of mergers washed over the country.

Industrial developments and the organisation of research activities in Germany have been an important source of inspiration for Dutch industries. Many new research-labs were founded, not only in the food-industry, but also in other economic sectors. Even before World War I several industries had already set up their own research facilities. The Wageningen School for Agriculture was most influential in Dutch

[8] Vereeniging van de Nederlandsche Chemische Industry, transl. Society of The Dutch Chemical Industry

agriculture and food sector, and it had started its research activities from its very beginning. Also, the Delft School for Technology had research departments in chemistry and geodesics. However, the Delft research departments had a reserved attitude toward cooperation with industry, because they considered that their primary role was in research and education, but not in industry. This was basically the reason why the Nederlandsche Gist and Spiritus Fabriek[9] already in 1885 started its own research department. The company could only be in step with international developments by starting its own research activities. Before World War I research laboratories were founded by the Bataafse Petroleum Maatschappij (oils) between 1906 and 1909 and in 1910 Philips started its famous Natuurkundig Laboratorium, better known as Philips NatLab (electronics and physics).

World War I had created totally new circumstances for the Dutch industry and some companies changed their policy. Noury & van der Lande set up a research department, but changed from food to chemistry. Jurgens (margarine) stepped into research and extended its products to non-foods (soap). Also Van den Berg (margarine) started a small research lab. When Jurgens, van den Berg and the Lever Brothers founded Unilever in 1928, it had one of the larger research departments in the Netherlands. By 1937 it had already thirty employees.

Research laboratories were also to be found in the pharmaceutical industry, most notably at Brocades and Organon. Several of these laboratories were active in the overlapping areas of food, (bulk) chemicals and pharmaceuticals. Most of the other research laboratories in the chemical industry were oriented to the production of minerals and derivates. Important players were for instance ENKA and HKI (rayon), the State Mines/DSM (coal, cokes and bulk chemicals), Gouda (candles). Cooperation between several of these research laboratories has given Dutch chemical research a very good reputation, especially in the field of catalysis, for which it was famous in the nineteen fifties (Homburg, Rip and Small, 2000, pp. 299-315).

Chemistry, agriculture and the food-industry have strongly influenced each other. The discovery of super-phosphate for instance, has marked the beginning of the artificial manure industry. Thanks to the use of chemical manures, a sharp increase of agricultural production was made possible, and on the waves of this production an extensive food-industry came to life. Together with the machine-industry it formed a strong economical cluster.

The Dutch chemical industry was however, a rather fragmented industry. Compared to the powerful German chemical industries with its sizable research departments, the Dutch industry lacked size, scope and self-confidence to be on the leading edge of technology. However, its overall performance was not bad at all (Homburg, 2000, pp. 317-331).

Increased agricultural production and more generally, advanced knowledge about nutrition value have boosted the development of several new products in the food-industry. Increased knowledge has also boosted growth of the food-sector as a whole, as well as growth in adjacent sectors, such as the chemical and pharmaceutical industries. The production of margarine, for instance, was initially based on a well-defined process with a known set of ingredients and procedures. However, as knowledge about edible fats increased, several alternative ingredients and procedures were developed to reach the same result. The technological innovation of catalytic hydrogenation allowed the margarine industry to use vegetable raw material instead of animal fats. In the slipstream of that same development, margarine factories acquired cocos-palm plantations in the former colonies or used whale-oil in several production processes.

Yet, the knowledge about the properties of fats was not restricted to the food-industry. Also, the chemical and pharmaceutical industry have benefited from this increasing body of knowledge. Thus, parallel to food-production a chain of non-food applications was developed. Several oils which could be used in the food-sector were also the basic ingredient in the paint industry. Unilever for instance started productions of foodstuffs, but also the production of soaps and candles, basically using the same raw material. Cacao-butter for instance is widely used in food-products, but also in the pharmaceutical and cosmetics industry.

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9 Nederlandsche Gist- en Spiritus Fabriek, transl. Dutch Yeast and Methylated Spirits Factory

Chemistry and food-industry thus, developed along parallel paths and formed a strong cluster, often crossing the borders between both sectors. The chemical/food industry has synthesised a range of artificial tastes, odours and colouring agents to be used in foodstuffs. Increasing knowledge about chemical processes has been parallelled with the increase of knowledge of biological processes. However, the chemical industry in the Netherlands had a different specialization pattern than in neighbouring Germany. Whereas the specialization pattern in Germany tended in the direction of pharmaceuticals, the chemical industry in the Netherlands held much stronger links to the food-industry, bulk chemicals and the petrochemical industry (van Otterloo, 2000).

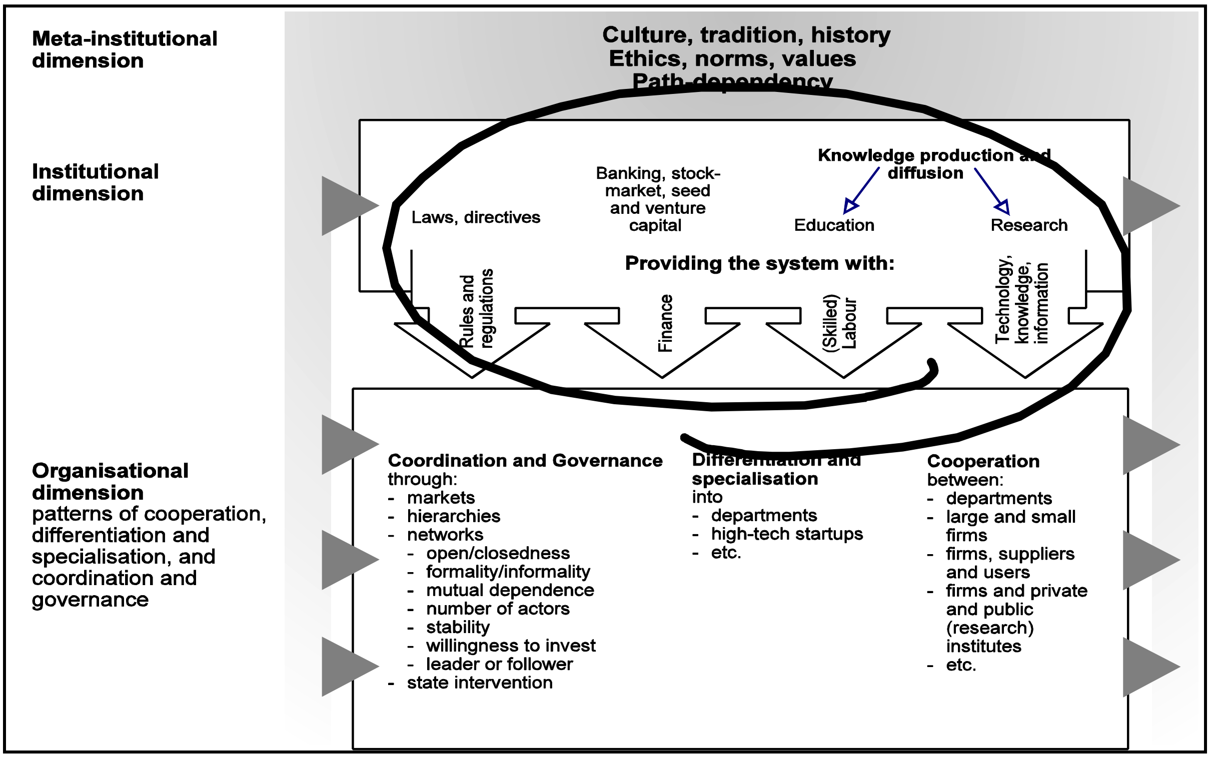

Figure 38 *Concentration of innovative activities in sectors related to (modern) biotech*

The centre of innovativeness in the sectors related to (modern) biotechnology was much more rooted in the institutional than in the organizational dimension. Especially the developments in agriculture have been such that the Ministry of Agriculture, Nature Management and Fisheries could develop into an expert system with an unparalleled reach. This expert-system of technological accomplishment and professional expertise has organised large areas of the material and social environment in which people live (cf. Giddens, 1990, p. 27). But the Ministry of Agriculture was also the key player in the generation and redistribution of resources. It is furthermore a key-player in the generation, implementation and adjustment of the regulatory system (van der Ploeg, 1999, p. 250). This Ministry has started to build that particular position in the period under review, with the setup of several institutional arrangements, providing important resources for innovative activity, but also with subsidies to shepherd farmers through the perils of the nineteen thirty's crises.

In the industrial sectors (foods, chemicals and pharmaceuticals) the focus was stronger oriented towards the development of innovative power through the setup of research laboratories, based on the models of German industries. The inspiration for these laboratories was found in Germany and many of the leading scientists were educated and trained in Germany. The Dutch research structure was basically a technology-follower, with an excellent performance in several niches, such as for instance in yeasts and margarine, and several small niches related to the meat-industries. On the whole, the institutional developments in the agricultural, food, chemical and pharmaceutical sectors stand out by their reach, span and influence in social and economical interactions.

4.4 Conclusions

The leading question for this research project is whether national-sectoral systems of innovation exist, and if they exist, how this system influences the innovative capacity of the sectors under review. Closely related is the question how a national-sectoral system has come into being.

We have compared the sectors under review on four items, the organizational structure, the institutional environment, sector characteristics and technology involved. Our conclusion is that the two sectors differ considerably. By and large we can say that innovation in the telecommunication sector has been relatively low, because the Dutch government and the operator had a clear preference for purchasing equipment from abroad, rather than setting up a genuine Dutch telecommunication industry, covering the whole range of telecommunication-apparatus (transmission, switching & end-user equipment). Yet, innovativeness in telecom may have been low in general, it has been high in some niches, such as transmission and system development, and in radio-technology. The reason for innovativeness was not so much in an industrial or scientific ambition, but rather the pure need to solve emerging problems. Radio-research only started when the Netherlands was excluded from international lines, which harmed its contacts with the overseas colonies, and its mercantile marine. Transmission research started when local efforts, which were meant to improve the performance of equipment, were too fragmented and threatened to influence the function of the network as an integrated system. Thus, transmission research and system development were centralised and coordinated.

The agriculture/food/chemistry-cluster has been very innovative, mainly for two reasons. First, Dutch agriculture traditionally had a head-start over other European countries. Second, the Dutch agriculture production was boosted by scientific efforts, because knowledge about new technology (especially regarding the use of chemical manure) was soon disseminated to local farmers and farmers were willing to pick up new technologies. Agricultural production was initially limited to local markets, but the surplus of agricultural production in combination with new preservation and conservation technologies, and a good infrastructure to transport products, allowed for an increasing export orientation. Furthermore, the agriculture/food/chemistry cluster was mutually involved in the setup of complicated production chains. The dairy industry specialised in cheese and butter, the meat-industry was the raw-material supplier for the pharmaceutical and chemical industry, and many crops were used in the production of food (as consumer products as well as semi-finished products for the food-industry), and also in the chemical industry.

For reasons of readability we have cut the table that we introduced in chapter two, into four pieces, thus covering technology, the organisational architecture, the institutional environment and sector characteristics.

		Telecommunication		***Agriculture/food & chemistry cluster***	
		1910	***1940***	***1910***	***1940***
Technology	*Type of innovations*	*incremental*	*incremental*	*incremental artisanal progressive*	*incremental artisanal progressive*
	Scope	*local*	*national*	*regional (inter-) national*	*(inter-) national*
	Leader or follower	*follower*	*follower*	*leader*	*leader*

Table 25a *Technology: the telecom and biotech sectors compared (1900 - 1940)*

Even though the general principles of telecommunication were relatively well known, innovativeness in the sector was very high. Products were improved over and over again. The capacity and speed of the switchboards increased, and they were automated, thus cutting the cost of a whole army of telephone operators. By and large it was a series of incremental innovations, although some had a profound progressive character, as for instance the automation of the switchboards. Yet the Netherlands was lacking a genuine Dutch telecommunication industry, and innovativeness mainly concentrated on minor adjustments to adjust equipment to the national telecommunication system. Thus, the telecommunication sector was rather a technology follower than a leader.

There were however few exceptions, such as in radio-technology and network management. Innovativeness in radio-technology had a more progressive character, but as soon as the basic principles were understood, the character changed towards more incremental innovations.

In the agriculture/food/chemistry cluster we also find many adaptive innovations, but also artisanal and progressive innovations. The use of chemical manure was such a progressive innovation which has boosted production and allowed for an increasing export-orientation in agricultural products. Next to increased production, there was also a strong tendency to improve quality through breeding programs in plant and animal technology. The basic principles of genetics were better understood and confirmed what Dutch farmers already had done in the past, although on a tacit level, namely to find the best combination in plants or animals. Knowledge, especially in agriculture was largely tacit, even though the body of knowledge was increasingly codified in research. It made the agriculture/food/chemistry cluster a technology leader, very open towards the application of new technologies, tools and methods.

				Telecommunication		**Agriculture/food/chemistry cluster**	
				1910	***1940***	***1910***	***1940***
Organizational architecture of the idea-innovation chain	*Differentiation*		*vertical*	*low*	*relatively low*	*low*	*low*
			horizontal	*low*	*relatively low*	*low*	*low*
	Division of labour			*low*	*relatively low*	*low*	*low*
	Mutual dependency			*linear*	*linear*	*flexible*	*flexible*
	Coordination		*within the company*	*hierarchy*	*hierarchy*	*hierarchy*	*hierarchy*
			between companies	*market*	*hierarchy*	*networks*	*networks*
		Mobility of:	*workers*	*low*	*low*	*low*	*low*
			staff & management	*low*	*low*	*considerable*	*considerable*

Table 25b *The organizational architecture: the telecom and biotech sectors compared (1900 - 1940)*

The setup of the idea-innovation chain in Dutch telecommunications largely resembled the process of industrialisation in other sectors and in other countries, where the bigger companies started to separate research from production and. As a result of this increasing division of labour, a sophisticated chain evolved, with departments for each phase of the innovation process. This process can be observed in telecommunication (the founding of R&D departments) and in the industrial activities, especially in the food and chemistry industry, and it is basically connected to the increasing scale of activities (the larger te scale, the more division of labour, the greater the need for coordination). However, here we find an interesting difference between the two sectors. The coordination mechanism of the idea-innovation chain within the companies, is the hierarchy, and the setup of the idea innovation chain is basically linear. Yet, there is a marked difference in the division of labour between companies. Innovativeness in Dutch telecommunication was low in the early days of telecommunication and if there was a coordination mechanism, it was the market. Later, when a small-scaled industry developed, it was PTT hierarchy that set the rules, the standards, the volume of production, etc.

In the agriculture/food/chemistry cluster we find an important role for inter-organizational networks. Farmers, breeders, industry, and public and private research institutes were mutually involved in numerous research innovation networks, which covered the full breadth of the sector, as well as they covered the full length of the idea-innovation chain. The cluster was a clear example of networking and the actors in the cluster were involved in numerous networks. Innovation was a typical moving back and forth, involving several parties and different sources of knowledge. However, even though there were many actors involved, the division of labour within organisations was rather simple.

The telecommunication sector had only few economic players. Mobility of workers, staff and management was correspondingly low. Workers made their career within the hierarchy, and there was some mobility within the company, although very modest.

Mobility in the agriculture/food/chemistry cluster was rather low for workers, but relatively high for staff and management. The reason is that management and staff were usually recruited from outside the region, to avoid a conflict of interest in the co-operatives.

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="2">Telecommunication</th><th colspan="2">Agriculture/food & chemistry cluster</th></tr>
<tr><th>1910</th><th>1940</th><th>1910</th><th>1940</th></tr>
<tr><td rowspan="8">Institutional environment</td><td colspan="2">Social embeddedness</td><td>narrow</td><td>narrow</td><td>broad</td><td>broad</td></tr>
<tr><td colspan="2">'Supply' of skilled labour</td><td>sufficient</td><td>sufficient</td><td>sufficient</td><td>sufficient</td></tr>
<tr><td colspan="2">Education</td><td>in company</td><td>in company</td><td>in sector</td><td>in sector</td></tr>
<tr><td colspan="2">Research funding</td><td>n.a.</td><td>public</td><td>public/private</td><td>public/private</td></tr>
<tr><td colspan="2">Impact of regulations</td><td>considerable</td><td>high</td><td>moderate</td><td>moderate</td></tr>
<tr><td rowspan="3">Role of associations</td><td>training/ education</td><td>none</td><td>none</td><td>major</td><td>major</td></tr>
<tr><td>finance</td><td>none</td><td>none</td><td>considerable</td><td>considerable</td></tr>
<tr><td>regulation</td><td>none</td><td>none</td><td>low</td><td>increasing</td></tr>
</table>

Table 25c *The institutional environment: the telecom and biotech sectors compared (1900 - 1940)*

The societal embeddedness of the two sectors differed considerably. The telecommunication industry, with its inner-orientedness and only few links to the outside world, was in fact a world within itself, for instance, with specialized education and a sector specific diploma structure. It lacked the independence of a normal company and could only grow within the limited space that was offered by government and parliament. This was a marked difference with the agriculture/food/chemistry cluster. Especially in agriculture there were numerous small farms, each strongly embedded in local communities. These farms were highly mutually interdependent, through family-ties, neighbourliness, religion, politics and social life. They were also interdependent through the participation in several co-operatives, councils and advisory bodies. Thus, the societal embeddedness was rather broad and encompassing.

The supply of skilled labour was sufficient in both sectors, even though there were some marked differences. In telecommunication there was no adequate (vocational) grounding for technicians, but this did not pose a real problem. Training was organised as a combination of self-study and in-company training programmes. The agro/food cluster had its own system of preparatory training, under the responsibility of the Ministry of Agriculture. This was an exception in the Dutch education system, because all other preparatory education was organised under the responsibility of the Ministry of Science and Education. The basic reason was that educational activities in agriculture were tailored to the requirements of the sector. Thus, courses were organised during the winter season, when farmers and farmhands had time to attend schools.

Research funding in telecommunication was a matter of allocating a percentage of the general PTT budget to research activities. It was public in nature, because PTT was a integrated office of the Ministry of Transport and Water Management. In the agro/food/chemic cluster, we find several private and public funding structures, as well as combinations between the two. The differences between the research institutes were mainly technical, covering different fields, but their general attitude was largely comparable: to provide the customers (whether government, industry or farmers) with independent information and expert knowledge.

The impact of regulations in telecommunications used to be relatively low, when the technology was introduced, but increased with each step towards a national monopoly. In the early twentieth century, when government was acquiring the local networks, it was already considerable, but by the end of the period under review, the impact was high. Regulation in the agro/food/chemical cluster was already moderate and government involvement was still increasing, for instance in land reclamation programmes.

The impact of associations in telecommunications in the fields of training, finance and education was rather low. In the agro/food/chemical cluster it was rather high. Training and education was organised in the sector. The curriculum was tailored to the needs of the local or regional company-structure, and representatives of societal bodies and -councils participated in the advice structure of the school-system. Representatives also participated in exams as second examiners. In finance we find a similar structure, because loans were basically provided by co-operative banks. The executive board and the supervisory board of these banks were recruited from local farmers, who usually held close ties to other societal bodies. The role of associations in matters of regulations was rather low, although increasing. The stronger the cooperation between farmers and the stronger the economic performance, the stronger the need for regulations. Several research institutes were founded to warrant the quality of agricultural production. With the foundations of such institutes, the agricultural community accepted its rules and regulations.

		Telecommunication		**Agriculture/food & chemistry cluster**	
		1910	**1940**	**1910**	**1940**
Sector characteristics	*Economic orientation*	*public service*	*public service*	*growth*	*growth*
	Market	*open*	*open*	*open*	*open*
	Players in the market	*few*	*few*	*numerous*	*numerous*
	External relations	*few*	*few*	*numerous*	*numerous*
	Pattern of specialization	*trans-mission*	*trans-mission*	*high volume/ low prices*	*high volume/ low prices*

Table 25d *Sector characteristics: the telecom and biotech sectors compared (1900 - 1940)*

The telecommunication sector was a small and closed sector, with only few economical actors and few external relations. It was a closed sector in that it had hardly any relations to other sectors. It was a sector with a strong inner-orientedness, holding high regards for technology. Its economic orientation was to provide a public service, at a reasonable price. It was a sector with only few actors with relatively stable relations. Yet, the market (for the purchase of equipment) was relatively open, even though there was a tendency towards a more uniform system, thus largely excluding competition.

The agriculture/food/chemistry cluster on the other side was especially open, with a broad, outer-oriented attitude. The more the elements of the cluster got intertwined, the more the sector was oriented towards exports. The sector comprised numerous actors, closely intertwined and with numerous external relations.

The policies of the local networks and the national networks were to purchase equipment from abroad. This posed some particular problems of how to adjust equipment to national system-characteristics. Here we find an emerging specialization in transmission technology and network-management. The agriculture, food and chemistry cluster already were already strongly oriented towards exports. Exports were further boosted, because the production-volume increased sharply by the use of chemical manure, and by developments in the transport sector. The Netherlands has traditionally tried to increase its international market-share, by putting large volumes in the market at relatively low prices. Bulk-production was the main strategy.

The most striking feature of these tables is that they hardly show any differences over time. If differences appear, they are largely the result of an increasing scale of production. For instance, when agricultural production was low, the products were mainly marketed and sold on the local markets. The economic orientation changed from a supplier of local markets towards growth through exports, which was the result of increased agricultural production. A rather similar example is to be found in telecommunications. The impact of regulations increased with the scale of the telecommunication network, from local networks to a national network. The more PTT tended towards a national monopoly, the stronger the impact of regulations.

Chapter 5: Restoration and modernization 1946 - 1975

> *The unique character of the fifties is to be found in the confirmation of the precious balance between tradition and modernisation; that fierce, yet controlled debate, in the public sphere as well as in the private sphere around the dining table, on how far to go in one's commitment to modernisation.*
>
> *Rigthart and de Rooy, 1997*

5.1 Introduction

World War II had left the Netherlands in a devastating state. The material damage was enormous, maybe even greater than in many other European countries. The important transport sector had come to a standstill as a result of heavy damages on bridges, roads, harbours, yards and infrastructure. Almost two/third (62 %) of the railroad network was out of order. The number of steam and diesel locomotives had dropped from 866 to 144. In electric locomotives the situation was even worse; 98% of all electric locomotives was lost or heavy damaged (van Zanden and Griffith, 1989; Griffith, 1984; van Zanden, 1997). Also, the dense network of waterways, rivers and canals was hard -if not impossible- to use. Devastation and vandalism had ruined sluices, flood-control dams and bridges. The transport capacity of 8,000 kilometres as it existed before the war, was virtually reduced to zero. The main ports of the Amsterdam and Rotterdam harbours were destroyed by depth-bombs, which not just damaged the embarkment and quay-walls, but also ruined the foundation of waterworks, ware-houses, silo's, cranes, elevators, coal-hoists and oil depots. In Rotterdam alone, seven kilometres of harbour-quay were damaged.

The agricultural sector had also suffered from the war. Large acreages of land were inundated or spoiled by salt water. Good arable land was used for fortifications, air-strips and other military use, and many arable lands were unsafe by mines. Approximately 18% of all arable land was useless just after the ending of World War II (Tromp, 1946; Messing, 1980, 1982).

The Dutch economy had come to a standstill and the Netherlands of 1945 was reduced to poverty. The production systems of large industrial plants like Shell, Unilever, Philips, Hoogovens and the oil refineries in Rotterdam were out of order. Jan Tinbergen, the famous Dutch economist put it like this in 1945: 'If we all hadn't worked for one year and in that time of vacation had spend 50% more than usual, than we would have found a slightly better situation when we came home, than it is to be found in the current situation.'

From the introduction it is obvious to see World War II as a watershed between the old and the new. Many societal and economic sectors had to be rebuilt, some even from scratch. It is thus tempting to see the end of the war as a starting point for the modernisation process that took place in the post-war years. Yet, that would be a denial of the important developments that already had taken place in the pre-war period, especially the developments in the late nineteen twenties and thirties. This period is to be seen as a forerunner of the modernisation-process that gained momentum in the nineteen fifties and sixties. Industrialisation, rationalisation, specialization and an increasing division of labour were already the adages of the pre-war years. The decision to automate the entire telephone network is to be seen as the crystallisation-point of that modernisation process that already stated during the Interbellum period. Most of the larger industrial companies had set up research departments. Also PTT had started to organise its innovative activities in research laboratories. By 1937 its Radio-lab had already 34 employees and the Telegraph and Telephone lab had 22 employees (van de Nieuwe Giessen, 1996). PTT serves as an excellent example of a firm that took the first steps towards modernisation long before World War II..

The first moves may have been made before the war, but fact remains that the devastations of war were such that the economy was thrown back upon its own few resources. How, then, is it possible that the Netherlands has recovered so quickly from the horrors of war? How could a country, where politics were traditionally divided along the lines of religious pillars and ideologies, develop the strength and determination for a fundamental and radical process of reconstruction, renewal and modernisation? This chapter will discuss the post war period, roughly from the end of World War II until the first oil crisis in 1973. It seeks to highlight the meta-institutional state of mind that stood at the cradle of the institutional constellation as it was to be found in the mid-1970's. Our intention is to analyse the cultural and institutional environment, especially the question how societal relations have developed among the main actors in the innovation processes.

We start our discussion with the developments shortly after the ending of World War II and we will argue that the decisions taken in those first years have dominated the political and societal landscape until the mid nineteen sixties. A most remarkable and strong driving force in these post-war years is a general held belief in the ability of science and technology to overcome technological, economical and even societal problems. This is not surprising, because the war itself has provided many examples of leapfrogging scientific results, especially in warfare. The fire-power of ballistics arms had been improved by the use of computers, which was a giant leap forward in a technological sense. But similar strong efforts were made in drug discovery. The use of penicillin to fight infectious injuries and diseases had become wide-spread. Thus, reaps of scientific progress were directly felt by many groups in society. Scientific progress became a target in itself. Furthermore, the Netherlands had to stand on their own feet. It could no longer join in with the economic and industrial developments in Germany. This atmosphere provided the right conditions for rational planning and radical modernisation, and these notions, with their strong sense of societal progress, have been the key-words of post-war development. These general notions were shares by government, industry, and the labour unions, and they found each other in a joined programme which intended to strengthen the Dutch economy in the perspective of international competition. On the whole, this has been a very successful approach and the Dutch economy has developed most prosperously throughout the period under review

Already we argued that some elements of the post-war institutional framework were not completely new. Some of them have harked back to the concepts of how to fight the horrors of the nineteen thirty’s crisis. The problem of unemployment then, for instance, was tackled by several governmental projects of agricultural engineering and land development for which the labour-power was recruited from the unemployed. It has been one of the first attempts in which government tried to soften the harsh effects of free enterprise, which had come to blossom on the waves of the second industrial revolution.

The attempts to fight the nineteen thirty’s crisis also marked a change of attitude in government. Until then, government had a rather passive attitude towards the economy, leaving economical development to the forces of free enterprise, but crisis forced government to take action. By doing so, government claiming a more central role in society. This was already the case in agriculture, but also in other economic sectors we can observe how the seeds for a planned economy with a central, leading role for government found fertile ground. This approach was further developed during the time of occupation in World War II.

The leading opinion at the end of the war was that the problems of backwardness, and the devastating effects of war could only be erased by radical modernisation. Ruling out social differences for the sake of reconstruction was the leading motto. Also, a system of planned wage-movements and prices was introduced. A new elite of experts, scientists and professionals entered the political stage and became most influential. Ideas about the close cooperation between government, the social partners and societal organisation were embodied in the ideal of statutory industrial organisations. This ideal was a point of reference in many economical sectors, but it especially came to blossom in the field of agriculture and adjacent industries.

We start this chapter with a brief discussion of the spirit of reconstruction and modernisation that has truly dominated the post-war period. Against this background we will discuss developments in the agriculture/food/chemistry cluster and telecommunications. As in the previous chapter, we will extensively discuss the case of agriculture, because it provides us with an excellent portrait of the spirit of progress that has dominated the post-war period. The agricultural sector has been an example of the determined belief in societal progress through modernisation, industrialisation and innovation. All developments in the sector were placed in the perspective of increased output, initially to feed the own population, but soon after in the perspective of growing exports, especially to feed the Treasury with foreign currency.

The case of agriculture is the more interesting, because government's set of supportive instruments has prospered particularly in this sector. These instruments have been a precondition for, as well as a result of the process of radical modernisation.

The sky-rocketing developments in agriculture, with its expanding, supportive system of research, education and information -the OVO triptych- have contrasted sharply with the developments in telecommunication. Whereas increasing agricultural output has largely exceeded demand in mid-1970 and even before, this was certainly not the case in telecommunication. Government held the telecommunication sector on the short leash and growth was strictly controlled by government and Parliament. In telephony demand largely exceeded production and waiting lists for a new connection have dominated the post-war period, with a peak in around 1965.

5.2 Restoration and expansion

The first five post-war years (1945 - 1950) have been a crucial period in the modernisation of the Dutch economy. The Netherlands had to find a balance between two basically conflicting interests: restoration on the one hand and modernisation on the other. Restoration offered the perspective of peace, rest and quietness after the chaos of war. It offered the illusion of safety, stable social and societal relations, and the familiarity of known concepts. Modernisation on the other hand, entailed the challenge of the unknown, and the excitement of new achievements. In influential circles of government, industry and academia, it was thought that modernisation could also provide a new mind-set to leave the past radically behind and free the country from its scientific, technological and social backwardness.

> Zum einen geht die Periode besonderes günstiger Wachstumbedingingen der Nachkriegszeit zu Ende; während dieser Zeit Können Störungen de industriellen Wachstum überwunden und eingetretene Entwicklungsrückstände aufgeholt werden. Zum anderen endet aber die trendperiode der industriellen Expansion, um ein stärker 'tertiär' geprägten Wirtschaft und Gesellschaft Platz zu Machen.
>
> Abelshauser, Die langen Fünfziger Jahre, 1987

Box 19 *The long 1950s*

The German historian of economics, Werner Abelshauser introduced the concept of 'the extended nineteen-fifties' as an explanatory-model for the breathtaking economic and societal developments in post-war Germany, a process which is usually summarised under the notion of the German Wirtschaftswunder. The Netherlands had similar strong developments 'le miracle Hollandais'. Messing (1989) has argued that the nineteen fifties and sixties have in fact completed what has started several decades earlier. The second wave of industrialisation, which already started in 1890, had fuelled a process leading to the industrialisation and up-scaling of many production processes and with it, to internationalisation, an increasing division of labour, rationalisation of work processes and standardisation. In this view the post-war period has strongly built on the groundwork that already was layed before the war.

The Dutch historian Jan Luiten van Zanden proposed -in the same line of reasoning- the concept of 'the long twentieth century'. The last stage of this era was the post-war period of reconstruction and modernisation, which was conceived as the years of 'the new arrangement'. In his view the 'long twentieth century' started in 1870 with a series of profound changes in business, industry, labour-market and government. However, the efforts of the main players in this process were uncoordinated, and hardly capable to fight the imperfections of the spirit of free enterprise. The Interbellum period was dominated by the tension between the old, nineteenth century liberal economic order on the one hand, and the new order of the anti-market-powers of the emerging welfare-state on the other. The Netherlands developed, on the ruins of the liberal world-order, a wide range of nationalistic, ad-hoc policies, to soften the harsh effects of the depression and societal exclusion. In the perspective of repair, reconstruction and modernisation of the post-war years, government, business and industry, and the powerful labour-unions found each other in a new institutional arrangement. In close cooperation these parties have put aside their differences and disputes that had kept them divided in their own camps for so many years. In a joint effort they developed a range of new instruments for a national economic policy.

It was a successful strategy in that a new societal elite of professional, experts and decision makers managed to motivate the country to adopt a new national identity: the Netherlands as a highly developed, industrial nation. Le miracle Hollandais of the nineteen fifties is to be seen the last stage of three long-term changes which started in the late nineteenth century: the development of a modern industry, the creation of the modern labour union, and the emerging welfare-state.

World War II, thus, may not have been the cultural and economic watershed between the old and the new, but the German occupation has certainly provided a set of instruments for the more active industrial policy that has marked the post-war period. The system of a central planned economy was introduced during the occupation and it has provided the opportunity for government to gain authority over consumption and production in industry; to develop an active system of price control; and to interfere in industrial relations, as well as in terms of employment. This attitude has marked the period of post-war reconstruction and expansion. (cf. Schuyt and Taverne, 2000, Abelshauser, 1987, van Zanden, 1997)

A red thread throughout the Dutch history is the fight against the water. Each flood-disaster challenged the Dutch to design new approaches; each attempt more daring than the previous. Hendrick Stevin drew the outlines of such a bold plan in 1667 in which he proposed to build dikes between the West Frisian islands. However, it was only in the twentieth century that the Netherlands finished some major waterworks and thus shortened the Dutch coastline considerably. The table below gives an overview:

Year	Coastline in km.	Waterworks
1930	1,950	
1932	1,650	Afsluitdijk
1950	1,585	Brielse Maas and Zuider Sloe
1952	1,560	Braakman
1954	1,550	Repair dikes after 1953 flood disaster
1986	850	Completion Deltaworks

Table 26 *Shortening the Dutch coast-line*
Source: Geuze and Kamphuis, 1997

The post-war period has indeed been a period of remarkable recovery and expansion. Remarkable, because there were two -basically conflicting- economic paradigms. On the one hand there was the open-market economy, an open system whereby the market is the central mechanism for coordination. In this approach government stands aloof toward interference in the private sector. On the other hand there were also the ideas for a planned economy whereby government has a strong influence through its active industrial policy, control of wages and prices, progressive tax rates, and the development of the welfare state (Messing, 1981). In the latter way the Netherlands tried to implemented the core of Keynesian thinking: active government interference trough economic politics and social policy, aiming at the creation of employment, social security and prosperity for all.

1951 has been an important year in the process of post-war reconstruction. In that year the phase of reconstruction changed into economic expansion. A period of continuous growth followed until 1973, especially fuelled by increasing exports and industrialisation. The Dutch economic success is usually attributed to two factors. First, Dutch products could meet international competition at equal level, because a good product was offered at a relatively low price. This was made possible because government and the social partners had mutually agreed on a central policy for the wages and prices. A second factor was that the production capacity of industry was radically extended and modernised (van Zanden and Griffith, 1989).

Post-war decision makers had extremely high expectations about the role of science and technology. These were regarded to be important economic production factors and could be used to maintain and increase the competitiveness of the Dutch economy. In line with this thinking the Dutch industry heavily invested in research and development programmes. The important role of science and technology was not just limited to industrial processes or technological innovations. Science and technology were also used to reach beyond the political differences that had separated the Dutch political landscape for so many years. The role of expert-opinion was increasingly important in virtually all sectors of the economy, but also in societal matters. Science and technology played the leading role in the design of industrial products, as well as in the design of urban renewal, or the design of a desired social configuration. Consensus about the 'make-ability' of society through technological plan-procedures has dominated decision making throughout the post-war period. This was apparent in the design of the macro-economical policy as well as in major infra-structural works like the Delta-works, the national systems of highways, the reconstruction of Rotterdam's inner-city and the social-economical development of deprived regions.

Especially the influence of mathematicians and statisticians has been remarkably strong. These experts have had a say in virtually every subject. Their influence was felt in the classical disciplines like economics, urban/rural planning and in other economic sectors -like finance and insurance- which have traditionally used numbers in the definition of problems and in the calculation of solutions. Yet, government and societal organisations adopted the mathematical way of thinking also in other fields, as it provided the means to overcome fundamental differences in culture, philosophy of life and religions (Alberts, 1998).

Enthusiasm for planning, technology and scientific solutions went hand in hand with a decreasing importance of ideology as a guiding principle in societal matters. This is the more remarkable, because the Netherlands has traditionally been divided along ideological, religious and political lines. This 'pillarised system' of confessional and ideological parties has proven to be remarkably resilient as it was soon revived after the war.

The character of post-war technology and industry-policy was presented as a pragmatic compromise, providing room for technological development and modernisation in whatever kind. This attitude was on the one hand fuelled by a strong belief in the powers of science and technology, but on the other by the fear of lagging behind in international competition (Dercksen, 1986).

The increased importance of mathematics and statistics has led to the setup of several influential statutory bodies, like for instance the Central Planning Bureau (1945) and the Social Economical Council (1950). The reach of the Organisation of Applied Technological Research (TNO) was also extended, as well as the organisation itself. Several new public research institutes were founded in these post-war years. The Mathematical Centre (1946) is a prototype of a government funded, but independent public body for (non-normative) scientific research. Its aim was to extend scientific knowledge on the one hand, but on the other to serve the broader society in the application of mathematical thought. Also in the field of nuclear science a research organisation was founded (FOM), and these initiatives were later coordinated by the Dutch Organisation for Fundamental Scientific Research (ZWO). The funding of research and development activities and the extension of the scientific infrastructure has been the core of the Dutch industry and technology policy (Schuyt and Taverne, 2000, pp. 120-123).

5.3 Agriculture

No societal sector has undergone such radical changes as agriculture. Agriculture started to develop most prosperously since the beginning of the twentieth century, but the crisis of the nineteen thirties and World War II was a period of serious stagnation. During the crisis many countries closed their borders for Dutch agricultural products, which resulted in a surplus of agricultural products and low prices. Government was forced to restrain production. The Dutch agricultural policy was used as an instrument to fight poverty and unemployment. Food supplies have especially been critical during the war. The organisation that was initially built up to fight the crisis was remodelled into an organisation for food-supply.

The struggle against poverty and the supply of food have been central in the first post-war years. However, later agriculture began to play an even more important role in bringing in foreign currency to fund the general process of reconstruction and modernisation. Huge efforts were also made to modernise and rationalise agriculture itself. Expansion, modernisation and industrialisation were the key words in these developments. A system of price and income-support was developed. The corporatist system of the statutory industrial organisation embodied the contract between government, politics and the farming community. Here we find the commodity boards for branches of agriculture (poultry, fish, pigs), commodity boards for a range of products (eggs, meat, dairy, etc.), and the system of agricultural boards.

The prime target of the Dutch agricultural sector was to gain an extended share of the common European market. Production and exports have grown faster in the Netherlands than in other European countries. A high level of productivity has guaranteed the Dutch farmer a relatively high income. As a result, the loss of employment in agriculture and related sectors has been comparatively low in the Netherlands.

5.3.1 Instruments to promote innovativeness; the OVO triptych

Already during the post-war years the Netherlands had developed a system of agricultural research, information and education, to support the agricultural sector and coach it in its process of change. This system is commonly is known as the ‘OVO-triptych’. It is characterised as a triptych, because the instruments are strongly intertwined and are very much part of the same government-funded support structure, which was the backbone of the expert system that gradually developed during the post-war years. The first steps in the setup of the support structure are made at the end of the nineteenth century. From its start in 1890 with a state-agricultural teacher for each province, the agricultural advisory service had developed into an organisation with 150 professionals by 1940. However, it has strongly expanded its reach and fields of expertise in the post-war years. By 1960 it had 1,700 employees with a high degree of specialization, which covered virtually every field in agriculture. The OVO-triptych has strongly contributed in the strengthening of competitiveness and has helped to make the best of opportunities (cf. Peper, 1996). We will briefly discuss the elements of the post-war OVO-triptych.

Research in agriculture

Public research in agriculture has been organised at three levels, universities, institutes for applied research and institutes for practical research.

The core of basic research, as well as scientific education is in the Agricultural University Wageningen and in the faculty of Animal Healthcare of Utrecht University. Typical for the Dutch approach is the integration of different dimensions in multi-disciplinary education programmes (basic subjects, technology and social sciences). The agricultural education and research programmes are also characterised by an integral approach of problems related to the food-chain (market, consumers and food), as well as problems within the spacial dimensions (agriculture, nature, ecology, recreation). Thus, the agricultural research and education programmes are a mixture of the natural and social sciences, and are developed within the basic disciplines in chemistry, biology, economy, sociology, etc.

The institutes of the Ministerial Office of Agricultural Research[1] (DLO) and some of the institutes of the Netherlands Organisation for Applied Research (TNO) have specialised in applied scientific research. Both DLO and TNO have sought to find answers in matters of botanic, vegetable and animal production, agro-industrial production and matters of environmental planning.

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[1] The Office of Agricultural Research was a unit of the Ministry of Agriculture, Nature Management and Fisheries. The institutes are usually addressed as the DLO-institutes, which is the acronym of the Dutch words ***D****ienst* ***L****andbouwkundig* ***O****nderzoek*

AB-DLO	Durable agrarian production
ATO-DLO	Agro-technology
CPRO-DLO	Plant-genetics
IBN-DLO	Nature research
ID-DLO	Animal research
IMAG-DLO	Agriculture and environmental technology/protection
IPO-DLO	Plant patho genetics, plant life and plant protection technologies
LEI-DLO	Agrarian economic institute
PUDOC-DLO	Scientific information and electronic publishing
RIKILT-DLO	Quality and safety of Foods
RIVO-DLO	Fisheries research
SC-DLO	Green (public) space

Table 27 *The former DLO-institutes*

At the level closest to farmers' and breeders' interest, we find a broad range of practical research institutes. Farmers and breeders not only benefited from the knowledge that was generated, they were also involved in the institutes' funding structure. The practical research institutes were partly funded by the Ministry of Agriculture, Nature Management and Fisheries (Ministry of LNV). The rest 50% was funded by farmers and breeders through a levy tax to the statutory agricultural organisation. The system of practical research has entailed nine sectoral experimental stations and over forty regional research centres. The scope in research has been strongly oriented towards sector-specific, and region-specific agricultural production. The system of practical agricultural research has often been addressed as the incubator for innovations.

Parallel to the public research structure, there was also a structure of privately funded research institutes. The Netherlands Institute for Dairy Research (NIZO) is a good example of such an institute. It is funded by the dairy industry and it was basically involved in lactic acid-based research. It gradually has broadened its scope towards food and pharmaceuticals. NIZO has started as a privately funded research institute, but the nature and reach of the organisation is largely comparable to public research institutes.

Advice and consultancy in agriculture

Advice in technical-economical matters was organised in the Office of the Agricultural Extension Service. The specialization pattern of this service was basically rooted in agricultural sectors and it had offices scattered all over the country. The Social-Economical Extension service had a regional orientation and used to be closely connected to farmers/breeders interest groups. A range of advisory activities has also been performed by the (food) processing industry, suppliers and private consultancy firms. Furthermore, there has been a range of activities and short courses organised by the agricultural schools, the innovation and practical centres and the system of higher education.

Education in agricultural sciences

Agricultural education has been strongly oriented towards practical knowledge. The agricultural winter-school has been the backbone of the secondary, agricultural education programme until World War II. Yet, on the waves of the extension of the Dutch education system, the agricultural research system was reconstructed along the general lines of the Dutch education system and entailed three levels of secondary education: a lower level (along with general technical education) a middle level and higher level, which consisted of several agricultural colleges and the agricultural university. This system provided education programmes in all fields of agriculture such as arable farming, cattle breeding and dairy farming, horticulture and forestry, fisheries, etc. Furthermore, it offered education programmes for the meat-industry and -retail, as well as for food sciences.

An interesting feature of agricultural research is that it is fully funded by the Ministry of LNV and not by the Ministry of Education, Culture and Science. Even though the analogy between the general and the agricultural education system has grown throughout the post-war period, it highlights the strong alliance between government and societal mid-field, with the close entanglement of farmers/breeder's organisations with political organisations, cultural, religious and social organisations, banks, industry etc.

5.3.2 Major developments in agriculture

Agriculture has developed from small-scale, mixed culture farming into large-scale specialised agro-business. The production of field crops, dairy products and meat has been integrated in the industrial chain of food-production. Strong links were also developed towards the chemical industry. Agricultural production supplied industrial production processes with raw materials, such as for instance in the starch and straw-board industry.

Several elements have facilitated this process of integration and upscaling. Technological innovations generated by research institutes, often in close cooperation with farmers, have provided improved knowledge of breeding and refinement of plants and life-stock. Yet, this was not an entirely new phenomenon. Farmers in Holland (mainly the western regions) have already specialised in intensive forms of agriculture from the sixteenth century onwards. Furthermore, agricultural production and international trade went hand in hand. Agriculture has a history of dynamic innovations, long before the technological revolutions of the nineteenth century (cf. Bieleman, 1992). Technological innovations in the post-war period were especially oriented towards the process of increasing mechanisation. The industrial processes of up-scaling, internationalisation, rationalisation, division of labour and the like, have truly buoyed agricultural developments. New approaches in operational management have led to a specific pattern of specialization, upscaling and concentration of production units.

In current agricultural research there is the debate what has been the driving force behind the remarkable performance of the Dutch agricultural sector. Some, like the agro-economist de Hoogh (1987) have argued that the modernisation of Dutch agriculture is not so much a socio-political process. It is rather to be seen as the logical unfolding of economic relations of markets. Labour is increasingly expensive, while capital and energy are increasingly cheaper. This process, combined with new technological possibilities has fuelled developments in agriculture. The farmer in this view has a pivotal role in the process and the Ministry of Agriculture has in fact, no other option than to follow this process. Others, like the agro-sociologist van der Ploeg (1999) have argued that the strength of the Dutch performance is due to the synergy that was created between governmental projects and projects of business, the agro-industry, trade, science and individual farmers.

Take for instance the example of a seed-supplier in the Westland, the western region which is so famous for its cultivation of vegetables under glass. The seed-supplier cannot afford to supply a market gardener with low-quality seeds or to calculate a price too high. The market gardener will, no doubt, communicate his mis-content with his colleagues and this will be a serious threat for the seed-supplier. Thus, trust and trustworthiness are crucial in agricultural clusters with their typical dense network structure.

Vijverberg, 1996

Box 20 *The self-restraint of trust*

It is indeed amazing how the Dutch could integrate an increasing number of stake-holders in this process of modernisation. Dutch agriculture can best be understood as an economic cluster, a clustering of similar and mutually enforcing activities within a clearly delimited social space, which is beneficial to all participants (Porter, 1985). The advantage of such a cluster is not so much the physical proximity but rather the shared efforts in the creation and dissemination of knowledge, cooperation and trust.

The central function of a region lies in the ability to organise convergence of projects and synergy. Where projects of market gardeners, suppliers, sales-people, scientists and information officials converge, there is room for extra capacity, for a synergy. This process is further stimulated by decreasing transaction and transformation costs and the role of trust in mutual relations (cf. Nooteboom, 1999). This is basically what happened in the Dutch modernisation process in agriculture. It was built on the convergence of innovation projects and the synergy between actors involved in these projects. The better the achievements, the more attractive the project for its (future) participants, which is a clear example of an increasing-returns process. Van der Ploeg recalls Szerszynski, who stated that the expert system in agriculture has constituted actor-networks of which experts are the key members, but the reach of such a network is far beyond science to materially order society. Indeed, one can find many examples how discussions in agriculture have influenced not only the geographical landscape but have also influenced the social landscape, such as the separation between arable land and recreation lands (cf. Van der Ploeg, 1999 pp. 265-9).

The Dutch process of modernisation, in conjunction with its system of guaranteed prices for agricultural products, has basically served as a blue-print for European agricultural policies. A strong driving force behind this policy was Sicco Mansholt, first in the Netherlands as the minister for agriculture, but especially later, as the EU commissioner for agricultural policy.

The developments of the post-war period have had a dramatic impact in many respects. The social and spacial characteristics of Dutch farming, farms and farmlands which have been the result of many ages of traditional agriculture, have undergone dramatic changes in the post-war period. Until then the choice of crops, for instance, was determined by natural geographical conditions. However, modern approaches towards land reclamation techniques and the introduction of advanced machinery provided the tools for a radical re-design of the natural landscape. The variety of farm land was gradually reduced, the natural geographical relief was levelled out, the streambed of creeks and streams were canalized and the number of crops was reduced, just to concentrate on high-profit cultures. Lörzing (1995) wrote:

> ‘If there has been one sphere of interest where government, private persons, business and industry have demonstrated a harmonic whole to the outside world, it has been in agriculture. The corporatist ideal of one large family of bosses and workers has only been fulfilled in agriculture. Of all the dreams about statutory industrial organisations, which were cherished by the socialist/catholic coalitions, only the dream of the agricultural board has come true. The ‘Green Front’s’ success is the result of the post-war socialist/confessionalist’s intervention policy. ‘Make-ability’ of the agricultural industrial cluster and landscape has been the driving force for the Social

Democrats, while harmony in social relations was the focal point for the Christian Democrats. Together they have created a seldom seen example of government-interference in agriculture and the man-made landscape. Nowhere in Europe one can find an equal example of state interference, so much dominated by this political compromise. The modern Dutch landscape is furnished along the lines of milk-quota, construction permits and land planning. To a large degree government and government bodies decides on issues as the animals in the stable, the building criteria for that particular stable or the crops to be bred. But government also decides which wood-bank has to be treated like a landscape monument and which one has to disappear, or which bird to nest in a specific eco-system or territory.'

The process of government interference can be traced back to the end of the nineteenth century, already with the setup of the system of research, information and education (the OVO-triptych). Under the influence of the nineteen thirties crisis this system has been extended to a range of protecting measures to help farmers to overcome the problems of crisis in each field of agriculture: arable farming as well as stock breeding, market gardening as well as horticulture (Bieleman, 1992). The agricultural community accepted government's tightened grip on the sector, more or less, in exchange for government's massive support for the sector (approximately 25% of all government expenditure between 1933 and 1936 was directed towards the agricultural sector). As a result, government started to participate actively in decisions regarding production methods, operational management and distribution of products. All in all this has reinforced the creation of dense networks of societal and economic relations which came to play an important role in the distribution of foods, during the time of crisis and during the war. Shortly after the war, but building on this system of intertwined interests, the agricultural board was created, which has institutionalised the cooperation between government and the agricultural sector.

Two issues have been high on the agenda ever since: increase of productivity and fair income for farmers. The latter policy was executed by a system of guaranteed prices for the main agricultural products like corn and milk. This policy, with all its imperfections (such as the large glut of farm products), stood at the basis of the European agricultural policies during the latter half of the nineteen fifties and early nineteen sixties.

5.3.3 Extension, land and labour saving technologies

The general tendency of the post war modernisation process was to increase the productivity in agriculture per acre, as well as to increase productivity per hour labour-force, through a range of land- and labour-saving methods. Initially the emphasis was on land-saving methods, like land reclamations and impoldering[2] of low lands. However, these policies have their natural limits and from the mid-nineteen fifties the emphasis was rather placed on labour saving technologies, especially mechanisation. These policies demanded considerable investments for farmers. However, the costs of investments were hardly affordable for the smaller farmers. Many of them had no other option than to sell the farm, which provided the opportunity for others to extend their farms. This has stimulated the process of extension, upscaling and concentration, a process which was thought necessary for the development of a healthy and viable agricultural sector. The effects of this policy have had a great impact on the agricultural sector. The average number of milk-cows per farm has sharply increased throughout the twentieth century, from an average of 5.5 in 1910 to 45.7 in 1995. Until 1953 more than 92% of all the farms had less than 20 cows, but this has fallen to 18% in 1995. Below we have depicted a table, categorizing firm size and the number of milk cows. The results for poultry farms are even more impressive. In 1961 95% of all the poultry farms had less than 400 chickens each, but this number was too small to be prosperous. By 1995 only 33 % of all poultry farms had less than 400 chickens. However, by that same date 30% of the poultry farms had more than 10,000 chickens each. Also, the total number of chicken farms has fallen from 171,973 in 1961 to

[2] *Impoldering* is the container for several drainage-techniques, whereby the ground-water level is artificially lowered and the surplus of water is drained away. This technology was also used to win new lands, like for instance the Noord-Oost Polder and Flevoland.

2,488 farms in 1995. Thus, upscaling and centralisation have been key words in Dutch agriculture (Bieleman, 2000).

Milk-cows per farm	1910 Number of farms		1953 Number of farms		1995 Number of farms	
	Abs.	%	Abs.	%	Abs.	%
1 - 10	167,929	87	153,758	76	3,380	9
10 - 20	15,265	8	34,138	17	3,354	9
20 - 100	9,392	5	14,891	7	29062	77
≥ 100	0				1,669	5
Total	192,600	100	202,787	100	37,465	100
Average number of cows per farm		***5.5***		***7.4***		***45.6***

Table 28 *Firm size structure in the Dutch dairy stock in 1910, 1953 and 1995*
Source: Bieleman, 2000

This process of upscaling, extension, mechanisation, rationalisation and specialization was also stimulated by large land consolidation programmes. These programmes have developed into an outstanding example of how to adjust geographical, infra-structural and social conditions to the demands of modern agriculture with its claims for rationalisation and efficiency. The main target of these large projects was to open up an area by building new roads, waterworks, gas and electricity infrastructure, water-control and water-management, and land/soil enrichment.

The impacts of these land consolidation processes have been tremendous, not just because large sums of money were involved, but also because these processes have had a tremendous social impact. The programmes demanded the utmost of mutual trust. This could only be reached if the majority of landowners was willing to participate in this process of modernisation. The advantage of these programmes was evident, but these same programmes were also an easy source of conflict. For instance, if the soil-quality of the land-parcels was lower than expected.

The main strategy to overcome these tricky problems was to involve landowners in the process of decision making. Each project had a local land-consolidation committee, designated with the task to evaluate the value of land. These committees included not only technical professionals, but also local farmers of outstanding reputation. Thus, government, government agencies, farmers and farmers' organisations were strongly intertwined in a dense agricultural network, supported by the professional elite of researchers, information officials and agricultural teachers of the OVO triptych.

		area in hectare	number of parcels	length of parcel-borders in kilometre
Farm A	before	4.39	33	13
	after	4.11	4	2
Farm B	before	6.71	29	15
	after	6.43	5	2.5
Farm C	before	5.80	18	13
	after	4.77	4	2.5
Farm D	before	11.63	23	8
	after	10.22	4	2.5
Farm E	before	7.73	24	7
	after	5.73	4	2.7
Farm F	before	15.48	29	11
	after	15.00	4	2.7

Table 29 *Land reclamation and consolidation: six examples from the Staphorst region before and after the land consolidation project.*
The figures of farms A, B and C are taken from a project in 1939, the others of a project in 1952
Source: de Wolde, 1969

Land consolidation projects may have created favourable conditions for rational and efficient farming, but it was finally the farmer who had to learn how to make the utmost use of these new opportunities. On the one hand, he could rely on the OVO-system of research, information and education to support him in these efforts; on the other, he could rely on the dense social system, which included several interest groups of farmers and several representation systems, for instance in the agricultural board or district water board.

The impact of social networks on the process of modernisation cannot be underestimated. It goes without saying that the farmer was actively involved in all sorts of networks that were related to farming

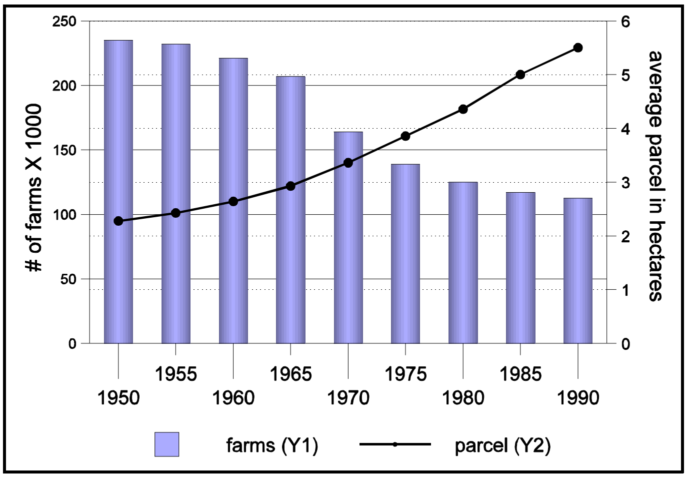

Figure 39 *Number of farms bigger than one hectare, the number of parcels per farm and the average size of parcels in hectares (1950 - 1988)*
Source: LEI/CBS

and the modernisation process. But the fact that also his relatives were involved in networks, closely connected to that same modernisation process reinforced the strength of the process. Usually the farmer's wife was also a member of social clubs like for instance the farmers-wives association (Boerinnenbond[3]). Children were similarly organised in youth organisations, with a range of social, educational and cultural activities. These organisations could on the one hand be characterised as social gatherings, but on the other they were important channels for the dissemination of innovations. Often these organisations organised courses which were related to general themes as bookkeeping, farm-hygiene, business economics or general themes as business-takeover. The same elements are also to be found in agricultural fairs. These were exhibitions of new products on the one hand and social gatherings on the other. Several contests offered the opportunity to demonstrate new innovations in ploughing, harvesting, milking, etc. A strong effort was made in the local community to strengthen the sense for modernity.

The relevance of land reclamation and land consolidation programmes is that they have demonstrated the strongly intertwined structure in the agro-industrial sector. Developments as they have taken place in agriculture were unthinkable without the existence of this strong body of intertwined relations between farmers/breeders, government, research institutes and industry. The OVO-triptych has not only provided the skills and knowledge for a radical change, it has also provided the legitimation for such drastic change under the flag of restoration and -especially- modernisation. The reach of these programmes has not only supported the change of technology, but helped to level out the social barriers to allow technical changes to take place. In that sense the land reclamation and consolidation programmes have been a focal point for the spirit of modernisation that has dominated the post-war period.

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3 These social activities were very tight and stable networks. Membership of the farmers-wives association was of course reserved to farmers-wives, but these clubs were also organised along the dominant religious pillars. This provided the system with a very strong sense of belonging to a social category. Many programmes were a mixture of agricultural modernisation on the one hand (e.g. modern farming, the woman's role in farm-management, hygiene in dairy production), and societal-religious themes (e.g. modern motherhood, Christianity in modern life). This combination provided the networks with a strong sense of stability, shared norms and values and solidarity.

5.3.4 Post -war social planning

The modernisation of the agricultural sector has been most impressive. The old appearance of the countryside, which had developed as the result of ages has been radically ruled out. Creeks and brooklets were changed into straight watercourses and ditches, wooded banks were cut and changed into arable lands. Muddy sand-roads were solidified and straightened, unevenness in the surface was levelled out and parcels were standardised to approximate rectangular shapes. Many old farms disappeared from the villages and new farms were built in the country-side. The operational management of farms was affected by the wave of modernisation. Traditional farms with their mixture of arable farming, dairy-stock and market gardening were forced to specialise, whether in cattle-breeding, dairy stock, fruit farming, horticulture, arable farming and the like, each depending on the characteristics of the land and available infrastructure. This was a huge economical, geographical, but especially social undertaking. Government, together with the elite of plan-experts, semi-government agencies, farmers-organisations, and social clubs were the driving force behind these processes. This expert system was strongly motivated by the spirit of modernisation and the expected gains of increased prosperity, but also by the fear to lag behind in international competition.

> *Purification* and *planning* were the key-words in the process of modernisation. To get rid of the past, one had to be strong and not hesitate to take radical decisions. This was the general adage during, as well as after the war. The bombing of Rotterdam can serve as an example for this attitude. Immediately after the bombing, the fire-zone was expropriated by the city council, the ruins were cleared, including foundations, electricity and telecom cables, sewer, and water pipes. Thus, Rotterdam's city centre was ready for building, but this rigorous approach has also ripped out its heart. It seemed as if memory and history were wiped out in one blow
>
> *(Schuyt and Taverne, 2000, pp. 24-25).*

Box 21 *The compulsory regime of purification and planning*

We discussed the agricultural sector as an example for post-war development and this has raised the question whether developments in other societal sectors were as far-reaching as in agriculture? We tend to believe that the general ideals of the post-war period have dominated the social reconstruction of the Netherlands in a -more or less- similar way. The impact of change and modernisation may have been strongest in agriculture, but the ideals were also felt in other societal sectors. In the text-box opposite we give the example how the city-centre of Rotterdam was radically erased after the bombing in the first days of World War II, and this example can be used as an example of a basic strategy that was used throughout the post-war period, under the flag of reconstruction and modernisation. Getting rid of the past to make the giant leap-forward into the future was the general adage. In this attitude it did not need a war to turn the inner-city of many towns upside down for ambitious city plans. The modern city was designed according to the laws of business, efficiency and mobility. New combinations of living, working and shopping were tried more or less successfully. The ideas about modern 'suburbia' came to life: the modern, small scale district which included a range of educational, medical, social and cultural facilities. Such districts should included shopping facilities for daily requirements, such as a supermarket, a greengrocery, a pet-shop, a hairdressing salon, a post office, etc.. The inner city was reserved for special shopping.

The ideas behind modern city development have had a strong social-psychological impact, not in the least because they were often truly paternalistic in attitude. Each square metre in the public space had a specific function. Similarly, the floor-plan of new housing complexes carefully drew the places for furniture, the cupboard, the beds and the dining table. New in this approach towards city planning were the deliberately designed open spaces, which stood symbol for community spirit and democracy. A 'sense for community' was highly valued and the underlying notion of the experts was that the individual was expected to give up his/her own personal demands for a bigger cause. The wishes of the individual clearly just played a secondary role in social planning. An expert in social planning wrote at the presentation of a design for a Rotterdam district:

> 'We have deliberately abandoned from a pointless variation in style and form, because we trust that the inner social variation in the population will sufficiently manifest itself in the use of the community garden, in social activities and in the mutual relations; this will push the monotony and identity in shape to the background.' (Stam-Beese, 1954, cited in van Winkel, 1999).

Just as in the case of agriculture, where government has gained a central position in the process of modernisation, we thus find government in a prominent role in fields like city development and public housing, albeit, not so encompassing as in agriculture, where it virtually controlled all the aspects of economic and social life, such as the pattern of specialization and the size of the farms. But as in agriculture we find similar ingredients in the process of societal change, like the cooperation of several interest groups in dense networks with state and local authorities, government-agencies and experts. The central tendency in these networks was that all the participants have mutually agreed upon the basic rules of the game. Individual demand in virtually all aspects of social life was made subservient to the central sense of community and the process of modernisation. These ideals were strongly supported by an ever expanding system of supporting institutions, such as for instance in research activities, community development centres, agricultural extension services and the like. The institutional networks have in fact mutually agreed on the underlying notions about the direction and content of planned development. In these networks we find (organisations of) workers, farmers, citizens, local, provincial and state authorities, state- and semi-state agencies, and professional experts. The perspectives and direction that were layed down by these networks and their commitment and determination to build a modern society, were also used as strategies to smoothen societal differences. In this atmosphere it was fully accepted that government chose the general direction and prioritized the spearheads of social and economical development.

5.3.5 Structure of post-war agricultural research

Restoration and modernisation have been the key-words in post-war developments and the strength and impact of these words were most strongly communicated in society. Austerity was highly valued, as it was seen as each individual's contribution to the building up of the country. The general norm was to set aside individual interests for the bigger, general cause, and with this attitude each individual was expected to contribute to general prosperity and wealth. This massive belief in societal progress was strong, especially in the nineteen fifties and this has dominated the changes and the institutional setup of the agricultural sector. A tight network of relations was developed in order to increase agricultural production. Modernisation and increase of production became an end in itself, despite overproduction which was evident in many fields. The driving force of reconstruction and modernisation was embedded in the configuration of the meta-institutions and it has developed remarkable strength in the close cooperation between government, experts and professionals, branch organisations and societal organisations.

In agriculture this tight system of societal relations has gradually developed into an expert system. The future perspectives which were painted by this expert system were essentially based on expectations about future market developments and future technologies. It was widely assumed that future technological developments would provide better possibilities to convert input to output and, thus, would provide ever better opportunities for efficiency. This leap forward, based on future-expectations, became the target, as well as the legitimation of the Dutch agricultural policy. Even more important, it became the starting point for a range of specific interventions. Land consolidation projects, interest-subsidy programmes for investments, security-bond-funds, information programmes, applied research, production control, nature-policy, manure-policy and quality-policy, were all aiming to facilitate that giant leap forward. Each measure had a strength in itself, but the strength and encompassing impact were in the combination of programmes and policies. The policy of the Ministry of Agriculture has induced a self-fulfilling prophecy (Van der Ploeg, 1999, pp.263-5).

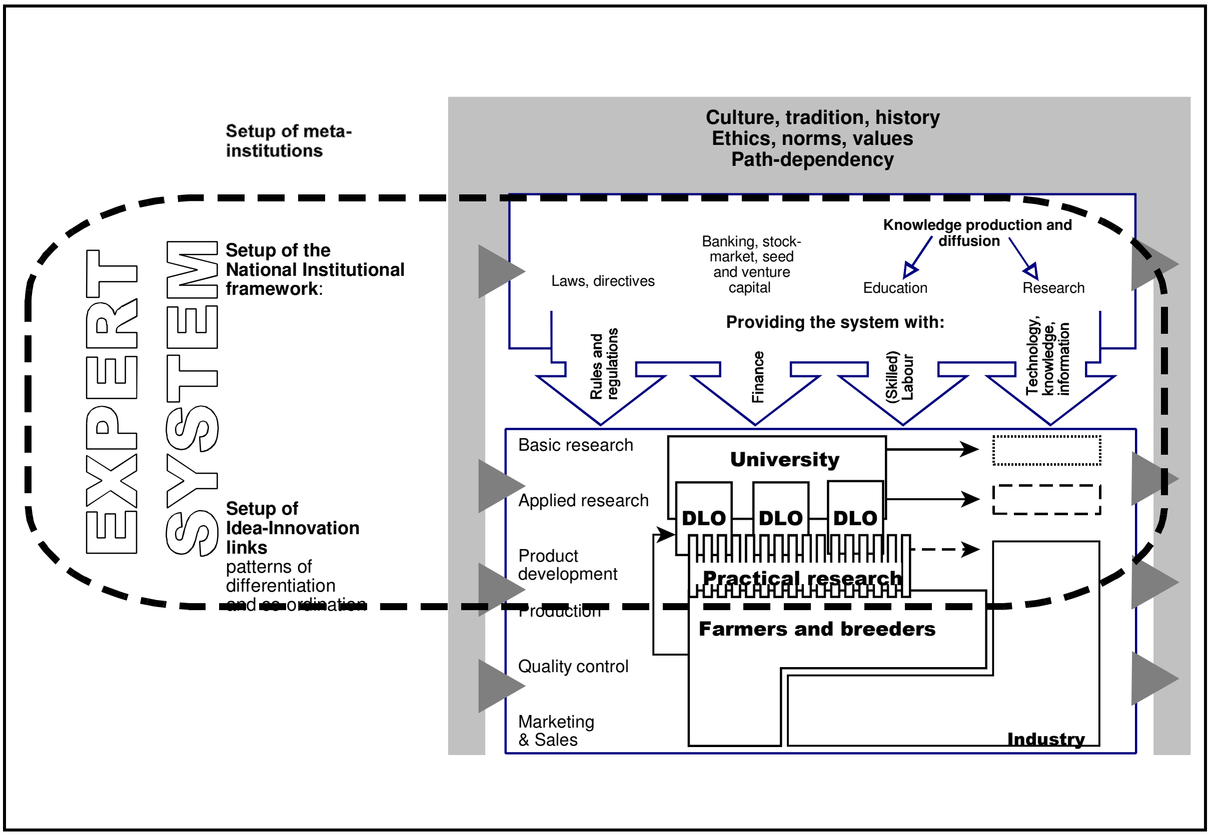

Figure 40 *Structure of post-war agricultural research*

Government involvement in agriculture in the pre-war years has mainly concentrated in the setup and extension of the national institutional framework. This system of tight institutional relations had an extremely wide reach, which even -to a large extent- covered the discretion of the individual farmer. On the one hand it facilitated and stimulated economic growth, but on the other it restricted farmers in their daily management. Farmers became part of an extended system of agricultural production.

This system could develop so prosperously because there was a high degree of trust among the players. Farmers were supported by an extended expert-system. This system has been developed to support developments towards an increased scale of farms, specialization, efficiency and modernisation. The legal concept of the private/public cooperation was developed in the statutory agricultural organisation, which gave these organisations a large degree of discretion. The system of banking and loans was very open and supportive to these developments, on the one hand because they were set up as co-operatives with strong ties to the agricultural community, but on the other hand because developments in agriculture were backed-up by large scale reconstruction plans and an extensive system of government subsidies.

Large flows of public funding were also directed to research- and innovation centres. These centres were part of the tight network of the OVO triptych, in which universities, agricultural research centres and practical research institutes were closely interwoven with the agricultural education system and the agricultural advisory service.

If we now concentrate on the chain of innovative activities, we can see that all activities in basic research, applied research, and product development, are done by this extensive expert system. This not only involved public knowledge institutes, like universities, research institutes, and testing stations. Also, many private research institutes are involved in this tight system of research. These institutes were directly funded by the industry, such as in case of dairy research, or they are funded by statutory sectoral organisations (PBO[4]). However, all these research-oriented institutes were particularly strong interlinked, no matter their funding structure. In general, the similarities between privately and publicly funded research institutes were much stronger than the differences between them. This tight research system used to specialise to the needs of specific economic sectors, but gradually new themes, with a more generic character have set the research agenda. For instance, NIZO, which was the research institute by the dairy sector for its own quality control, later specialised in lactic acid research, and still later opened up towards generic themes in food-research. The more knowledge about nutrition value and health effects cumulated, the vaguer the borders between food-, chemical- and pharmaceutical sector.

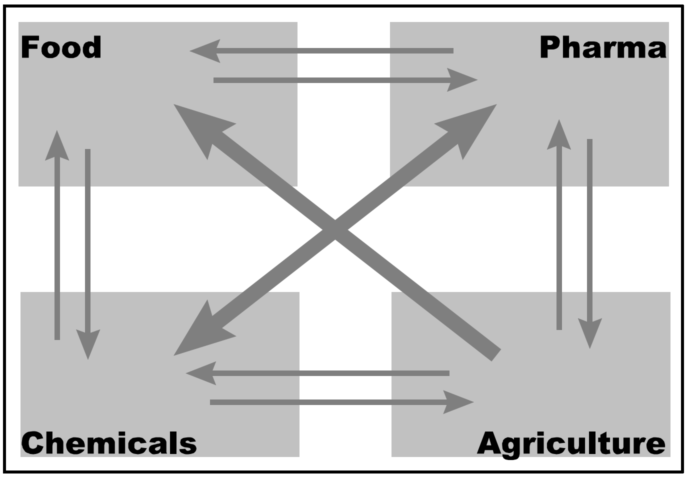

Figure 41 *Overlapping fields of research in the agro-industrial cluster*

However, it has to be noticed that the borders between agriculture, the pharmaceutic, chemical and food industry never have been really sharp in the Netherlands. There are several examples that research efforts in one sector have influenced research in other sectors. The relation between agriculture and food is rather obvious. The better the agricultural performance, the better the quality of food. However, the combination agro/food is also an important input for the pharmaceutical industry. Organon for instance, (now part of AKZO/Nobel) was a pharmaceutical industry which was rooted in the meat-industry. Organon was a leading producer of insulin. In reverse, the Dutch pharmaceutical industry has specialised in animal-medicine and vaccines. This is obvious for a country which is so densely populated by life stock (esp. cattle, pigs and poultry).

Also, the borders between the food-industry and the pharmaceutical industry are only thin. Foods with a clear health effect are developed at the overlap of the food and pharmaceutical industry. The links between food and (organic) chemicals are numerous. Gist/Brocades has a tradition in yeast production, with specialised products for the beer and bread industry, but it has also numerous links to the pharmaceutical industry. The chemical industry has been an important supplier for agriculture, especially in the production of artificial fertilizers, but it also uses agricultural input for chemical products. The potato-based starch industry is a good example where research is linked to pharmaceuticals, food as well as

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[4] The PBO (Publiekrechtelijke bedrijfsorganisatie) is a statutory industrial organisation which has been developed in the nineteen fifties. This organisation was recognised by government and had the right to impose a levy tax within the sector. This type of organisation has especially developed in the agricultural sector.

chemicals[5].

The role of industry has become increasingly important in the process of modernisation. Firstly as suppliers of agricultural goods, such as seeds, concentrates and fodder, but also as suppliers of fertilizers, pesticides, animal pharmaceuticals and the like. Industry was, thus, strongly interwoven in the tight network of agricultural relations. It had its own circuit of advisors and consultants, and these were closely interlinked to the public research and dissemination structure. The classical situation, whereby farmers and breeders directly sold their agricultural products to customers has gradually disappeared. Instead, a system was developed in which farmers and breeders negotiated contracts with industry. Thus, farmers and breeders were more or less 'reduced' to a single chain in the subsequent phases of the production process in many industrial fields.

The reach of the expert system is, however, not only limited to research activities. The system is also involved in quality control, marketing and even sales. Especially health-education has been a very important issue for the expert system, especially in the post-war years. The general view was that consumers had to be educated regarding matters of nutrition and health. Thus the circle of the OVO triptych has closed within the same expert-system. It generated knowledge in its research system, it educated the research findings to future experts and it informed customers about proper nutrition, hygiene, food, and health principles.

The pattern that has unfolded throughout the modernisation process can easily be regarded as a process to marginalise farmers and breeders as 'just another link in the chain', but that was definitely not the case. Van der Ploeg (1999) has identified seven distinctively different styles of farming within the apparently similar conditions of the Frisian dairy-farmers. Some farmers develop skills of breeders, while others place efficiency at the core of production. Some aim for the future, while others try to economize on resources. Each of these styles has unfolded next to the others. What seems to be undistinctive from the outside and certainly undistinctive for the layman, hides a world of variety, management- and innovation styles.

The innovation process in agriculture is thus, basically science and skill-driven, especially oriented towards an increase of efficiency and production. The power that was developed by the elite of politicians, scientists, experts and societal (branch) organisations provided a range of opportunities for individual farmers. Furthermore, the burden of modernisation was cushioned by the range of subsidies, which made it easier to be part of the process of modernisation, and the perspective of prosperity seemed to be within the reach of many.

The system of research, information and education was basically organised in such a way that it fitted the need of the farmers and breeders. The Wageningen agricultural university was active in basic, as well as in applied research. The governmental DLO institutes have specialised in applied research and the extensive and highly specialised system of practical research institutes was especially active in product-development. The setup of the latter institutes was such that they closely fitted the regional needs. The Boskoop-area for instance, which is famous for its variety of tree-growers. It had its own research-centre for tree-culture. The Lisse area, famous for its flower-bulbs, had its own specialised bulb-research centre. This list can be easily extended to each variety of agricultural production. It shows that the system of research, information and education was highly specializing, within the agricultural column. It was basically a vertical, top-down system of knowledge generation and dissemination, however, with bottom-up elements. The close proximity to the farmers and breeders, and their contribution in the funding and

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[5] AVEBE, which is the Netherlands-based, leading starch-industry sent out its 1999/2000 annual report with an ingredients-label on the cover. Next to cellulose and recycled paper (60 grams), pigments (61 grams), water (8 grams), glue and synthetic thickener (2.2 grams), it also contained 3.8 grams of starch and starch-derivatives. AVEBE is active in food and pharma, starch and animal-food, and industrial applications

decision structure warranted its place in the regional social and economical context.

The public OVO triptych was organised in such a way that knowledge could flow freely. Inventions were not patented and/or licenced. Inventions made by research institutes were disseminated through the system of information, advice and education to farmers and breeders. This system was tight; farmers were informed in lectures, experiments were cushioned by subsidies and farmers/breeders were coached individually through all the stage of the production process. This system of coaching and advise was part and parcel of the OVO triptych, but also of the advice and consultants structure of the agro-industry. This industry had its own teams of information-officers and consultants to coach the farmer in the application of new technologies, new materials, new methods. This private coaching structure seamlessly fitted the public OVO structure.

5.4 Telecommunication

In the post-war social-political climate, with its remarkable combination of high-pitched ideals, and rational, technocratic planning systems, it was fully accepted that government held tight control on the distribution of scarce resources and goods, public utilities and national/regional development programmes. Despite modern ideas, it was -more or less- accepted that, for instance, the production of houses largely lagged behind demand. Even though the problem of housing shortage was immense, government did not allow for a higher production, because -in the perspective of demographic developments- it feared to create an over-capacity, which possibly might have led to a surplus in the long run and thus entailed the risk of waking up the spectre of unemployment. Until the mid-1960's government was in the position to do so because it controlled the labour market as well as the rent-prices in the framework of its counter-cyclical policy (Schuyt and Taverne, 2000, pp. 195-201).

It was in this social-political climate that Dutch PTT had to recover from the war. The war itself had brought some important changes. The local Amsterdam, Rotterdam and The Hague networks were incorporated in the national PTT organisation. Furthermore, PTT had managed to gain legal independence. Both changes were only possible under the changed institutional regime of the German occupation. PTT had already desired legal independence in 1928, at the restructuring of the State Telegraph into PTT, but legal independency was never granted. The state wanted to hold tight control over the telecommunication sector, especially say over budgets and tariffs.

A new opportunity had loomed for PTT under the German occupation to reorganise according to the model of the German Reichspost. With its newly gained legal independence PTT hoped to free itself from the close ties with government. It expected to have more discretion to develop and grow like a regular public limited company and -which was its greatest desire- to negociate loans on the capital market for future investments. However, during the war as much as after the war, PTT has hardly enjoyed any advantage of this new-grown legal situation. It had taken over the local networks of the three biggest cities, but lacked the capacity and resources to fully integrate the three former city-networks in its general operations, and -de facto- these networks have lived a -more or less- independent life until the 1960's (Hogesteeger, 1989; Hulsink, 1996; Dek, Manders, de Vries, 1981)

The incorporation of the former city-networks and the change of the changed legal status which PTT had gained during the time of occupation, did not bring corporate freedom. During the war, the occupying forces held a tight grip on the telecommunication system for strategic reasons. But even the post-war years did not bring the freedom that PTT had hoped for. As all other societal services, PTT was called to the reconstruction of the country. Telecommunication was regarded to be of the utmost importance, especially in view of a balanced spread of industrial activity across the country. Government has granted PTT relatively large sums for investments in the telecommunication system in the context of that reconstruction-program, but this also entailed a reconstruction of the pre-war relations between government and the PTT. The ties were almost as tight as before. Yet, PTT did not complain, because the Ministry granted large investments for the reconstruction, especially in the first five post-war years. This almost erased PTT's biggest complaint, namely the restrictions on investments that it had felt so severely before the war. Yet, the pleasures of large investments were only short-lived. The drawback of the restored relation was that PTT was hit very hard by governmental budget-cuts during the Korea-crisis in 1950-51. The effects were so strong that PTT was forced to cancel several orders for switching equipment. Both PTT and PTI/Philips complained that these budget-cuts were square to governments industrial policy, but this did not help. PTT was fiercely curtailed PTT in its investments throughout the nineteen fifties (Dek, Manders and de Vries, 1981).

The matter of corporate identity has been a pinching matter that has exercised many minds. Initially it was proposed that PTT should keep its corporate identity, but this proposal had struck fierce resistence in Parliament. Part of the proposal was that PTT was allowed to build up a general reserve for future investments. The Second Chamber (Parliament) could not agree to this proposal, because it felt that this would curtail its own right of budget. As one of the members of Parliament put it:'It is unacceptable that PTT will develop into an island of prosperity in the sea of misery of the country's finance!'. Parliament insisted on keeping a tight grip on PTT, even though it had reconciled with a larger degree of corporate freedom for PTT.

PTT's management protested most strongly. In a letter to the minister it explained that it was on the verge of large investments, which entailed a heavy burden for the country's financial position. To avoid this, PTT suggested to negotiate loans on the capital market, which was a necessary step in her view. PTT furthermore argued that the build-up of a general reserve would only serve the stability of PTT's policy. Stability could be easily endangered if PTT's budget was restricted to the State's general financial framework. In its request PTT used the example of government's counter-cyclical policy to substantiate its allegations. This policy would curtail governments-investments in time of economical expansion, while PTT would under these circumstances meet an increase of demand at that very same time. These arguments, however true, did not mollify the Minister, nor Parliament. PTT lost its corporate identity in 1955 and was converted into a government-enterprise by the same date.

Year	Connections (thousands)	Growth (%)	Demand (thousands)	Production (thousands)	Waiting list (as % of production)
1940	322	-0	n.a.	n.a.	n.a.
1945	293	-9	n.a.	n.a.	n.a.
1950	509	74	49	60	82
1955	742	46	40	80	50
1960	1,044	41	36	94	38
1965	1,504	44	153	122	125
1970	2,202	46	140	243	58
1975	3,336	52	142	342	42
1980	4,892	47	98	379	26

Table 30 *Subscriber connections, production and waiting list 1940-1980*
Source: PTT annual reports/Dek, Manders and de Vries, 1981

PTT's management proved that it had foreseen developments well. From 1956 onwards PTT was indeed curtailed in its investments by government's counter cyclical policy and it could not meet the increasing demand for new subscriptions.

In the mean time, growth of demand has been impressive, especially after 1950. The cause of growth was on the one hand stimulated by increasing general prosperity, extended education and growth of the national income, but on the other hand by the increase of 'telephone-density'. The more telephones, the greater the attractiveness, and the greater the demand!

Government has kept its end up throughout the period under review. The sum of investments it made in PTT was larger than the revenues it gained from PTT. Only after 1973 it gained more than it invested. Yet, on the whole, regarding the post war period until 1980, it has gained more than it had invested (Dek, Manders, de Vries, 1981, p. 235)

Contrary to the agricultural sector, which was regarded to be an important spearhead of post-war economical development, and thus was supported with an ever expanding system of supporting arrangements and institutions, the development of the telecommunication system was curtailed by active government involvement. As a result, PTT was not able to exploit the full commercial opportunities which were offered by a general increase of prosperity throughout the post-war period. This particular situation has clearly set the agenda for the development of the telecommunication research activities. PTT's research activities were strongly oriented to get the utmost performance from the given network structure. Transmission technology, system-development and network management were the main subjects for PTT's research laboratories. It found a solid partner in Philips Telecommunication Industries (PTI) .

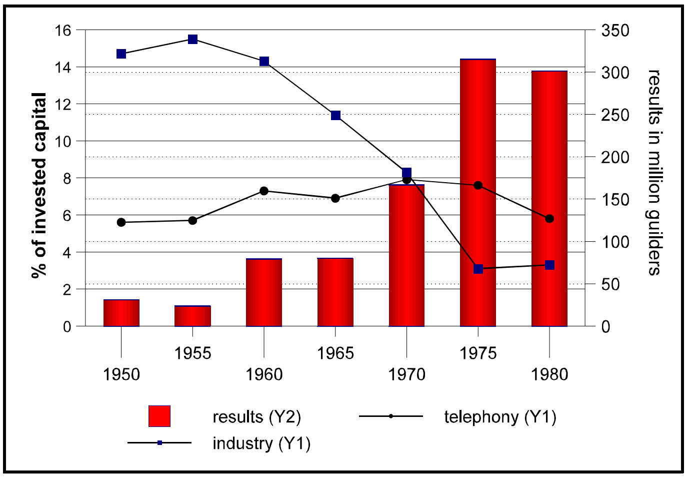

Figure 42 *Overall efficiency of the Dutch PTT compared to the efficiency of the Dutch industry (Y1 axis) and returns on invested capital (Y2 axis) 1950 - 1980*
Source: PTT/CPB

Rather than taking the general institutional setup as a frame of reference for the organisation of research activities (as in the case of agriculture), PTT has taken industry -especially PTI- as the main frame of reference for its research activities. Growth was not the leading adage in research activities, but how to get the utmost of a given situation.

In the sections to come we will first discuss the research activities of the main actors in telecommunication, PTT, Philips (especially Philips Telecommunication Industry) and the smaller suppliers Ericsson and NSEM.. We will start with a brief description of PTT's efforts to set up an extensive set of research activities during the post-war period. We will then turn to research activities at Philips. The focus will be on the general setup of Philips research activities, as well as on its research in telecommunication, and we will discuss how the general research activities are connected to the telecommunication branch. We will subsequently make a few brief remarks on PTT's suppliers without a research-department in the Netherlands, such as Ericsson and NSEM (later Alcatel). In conclusion we will discuss how the research activities of these actors were mutually connected.

5.4.1 PTT

Dutch PTT had two research laboratories at the beginning of World War II: the Radio Lab, which had specialised in long-distance transmission, and the Laboratory for Telegraphy and Telephony which had its specialization in transmission technology. During the war another laboratory was added to the PTT organisation, which was the Physics Laboratory of the former Armed Forces. This lab was involved in strategic telecommunication research, such as for instance in radar-technology. Yet, for strategic reasons it had managed to acquire a range of civilian contracts in the field of high-frequence research. Although there was a considerable overlap in the research-areas of these three laboratories, it did not lead to any cooperation, in fact, each laboratory lived its own, separate live.

In view of the post-war reconstruction an ambitious design was made for a new, centralised research-organisation. This plan entailed a central laboratory with four departments: (I) cables and amplifiers; (II) switching technology; (III) radio transmission; and (IV) business systems and telex-services. Each laboratory would be divided into three operational units: a research lab for basic research, an applied research lab and an engineering department. The character of this proposal was basically derived from customary practice within each field of technology. The research lab for instance, was the place to study technology on a fundamental level, the application lab was intended to study how new findings could be implemented in the telecommunication system and the engineering workshop was intended to actually build the applications.

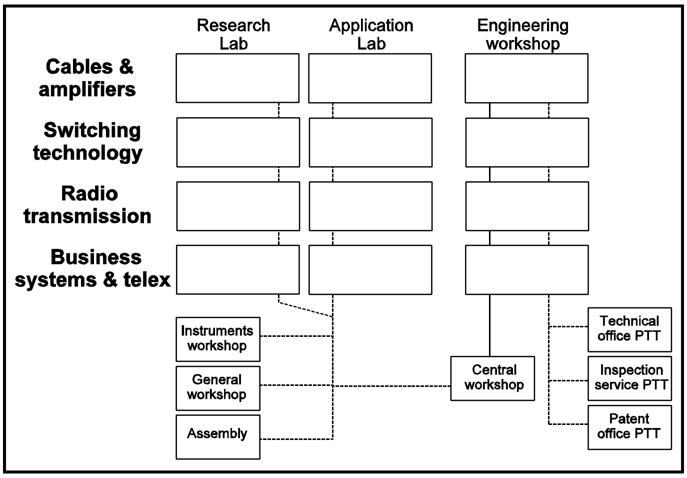

Figure 43 *Proposal for the organisation structure of a central laboratory for PTT*
Source: van de Nieuwe Giessen, 1996

The engineering workshop was an important unit in this design, because it was thought to be the linking pin, on the one hand to industry and manufacturing departments, and on the other hand to the laboratories and the technical (drawing) office, the patent office and the inspection service. Furthermore, it would be the supervisor of the central workshop. The latter unit was thought to be the manufacturer of equipment if production was non out-sourced to industry. At that time it was not uncommon that equipment, especially radio-equipment was built in PTT's own workshop, under its own control.

This proposal did not make it after all, but it still is interesting to mention, because it has marked an important turning point in the approach toward research activities. The formerly separated research activities (radio-lab and the T&T lab) were accommodated in a new comprehensive organisation structure. This structure provided on the one hand room to move for each functional department, but on the other hand there was an encompassing support- and coordination structure to fit the research activities in PTT's operational design. Integration and central control were the two basic elements of this organisation design.

This proposal tried to combine the best of a given practice, without the inefficiencies of that same practice. It was an attempt to streamline the then present research activities and it was thus strongly inner-oriented. The later proposals -which we come to discuss in what follows- were more outer-oriented. These proposals reflected an organizational setup which was strongly inspired by the way how the telecommunication industry had organised its research activities. Especially the US Bell-Labs and especially the Philips Physics Lab (Philips NatLab) have been important sources of inspiration for the design of PTT's research organisation. The initial design of the 1946 Central Lab for instance, was organised around the core of two laboratories, a physics lab and a chemical lab. Around the core thee additional laboratories were planned, one for radio technology, one for transmission technology, and one new lab for (switching-) equipment. This setup reflects PTT's initial ambition to be active in the field of basic research.

However, the implementation of the organizational setup of the Central Laboratory was rather a mixture of an industrial setup and common practice. The central role of the physics lab and chemical lab was certainly not established. These two elements remained rather small throughout the Central Lab's existence. The graph below gives a representation of the size of PTT's research organisation in 1950, when it had 204 employees and in 1955, when it had 292 employees. Each slice represents the number of workers.

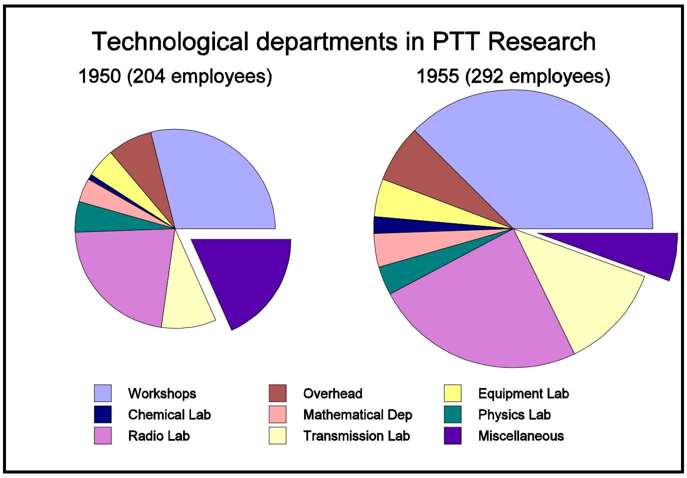

Figure 44 *Work force and division over departments at PTT's research organisation*
Source: van de Nieuwe Giessen, 1996

The largest department in the PTT research organisation was the technical workshop. This department, mainly manned by technicians, was meant to actually build prototypes. This work was done for the more specialised laboratories, yet in close cooperation. The technical workshop's task was also to implement the results into the existing telecommunication system. The second largest department was the radio-lab. Its main activities were initially oriented towards long distance transmission, but the scope of research has changed during the years. The water-flood disaster of 1953 in the province of Zeeland had revealed the vulnerability of a fully cable-based network system. An alternative for a cable-based system was the radio-beam link in the trunk network, and the latter technology has been the main field of activity for the radio-lab. The integration of radio and cable transmission has, in fact, strengthened and extended PTT's specialization towards transmission technologies. The latter two laboratories have also been responsible for the lion share of the laboratory reports and scientific papers in the 1950's. Together these laboratories produced 236 papers, whereas the joint result of all the other laboratories was 72 papers. The other labs were in fact, relatively small and were rather subservient to the transmission lab. However, some of these laboratories have been rather influential in a scientific sense, such as in the case of computer-development, where PTT has been one of the frontrunners (Hooijmans, 1981).

Two slices of the pie have been taken out as miscellaneous. In 1950 this slice represented the application institute, which was not viable as a separate department. Its role was later partly integrated in the smaller labs and partly in the general workshop. The 1955 slice represented the department of construction and development of radio-transmission, and it was especially active in telex and telegraphy. Its aim was to introduce teletype-writers which could be used by laymen, without any technical training. This was, however, rather an application task than a research task. Its focus was to improve the service, not to improve the technological elements.

	1950	1955
Overhead	4.8	6.8
Transmission	31.4	36.5
Workshops & applications	47.1	43
Small specialised labs	16.7	13.7

Table 31 *Main directorates in PTT's research organisation in 1950 and 1955 (share of personnel in departments)*
Source: Van de Nieuwe Giessen, 1996

The emphasis in the organizational setup -during these first ten post-war years- clearly reflect the changes of the design-paradigm for PTT's research organisation. The very first proposal was a clear attempt to integrate already existing research and development activities in a coherent organizational setup. This attempt can be regarded as an attempt to 'streamline' the research activities. The second design, actually the initial design for a Central Laboratory, was strongly influenced by the designs of research departments in industry, which entailed a strong massive core of fundamental research, surrounded by several application labs in several technological fields. Yet, despite high ambitions, this high-pitched design did not work out in practice. Basic research was an ambition too high. Research at PTT was meant to solve practical problems, to design an encompassing system of operations and to improve the performance of the network. The physical and chemical lab, which were intended to be the core laboratories were hardly developed after five years and from the beginning of the central lab, the emphasis in research was on applied research and system development. The 1955 profile is a clear confirmation of that trend. The emphasis in research was strongly oriented towards transmission technology. Not only the transmission lab, but also the radio-lab and a large part of the work-shops were involved in this research, or in the implementation of the results in the system. Even the specialised smaller laboratories were strongly involved in signalling and transmission technologies[6].

5.4.2 Philips/Philips Telecommunication Industry

Philips' first steps in telecommunication were in the NSF. Even when Philips owned the company, it still used the name NSF for three lines of products. (1) large broadcasting transmitters and radio sets, (2) radio communication equipment to be used in the military, aviation and shipping, and (3) components for transmission technology. The outburst of World War II has thrown a spanner in the works. Telecommunication equipment was regarded to be strategically important and Philips removed its production capacity to Australia. Its Dutch Laboratories, however, remained active in research. Philips' Physics Lab (Philips NatLab) started the development of a 48 channel system in close cooperation with Dutch PTT, which fits the pattern that Dutch telecommunication research was mainly oriented towards transmission.

Although NSF/Philips was active in all kinds of telecommunication transmission technology, it was not involved in switching technology until 1947. Dutch PTT had an outspoken preference for Siemens

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[6] One has to keep in mind that the research activities in transmission technology were not only oriented towards telephony. Transmission of telephony and telegraphy signals were localised in the range of narrowband transmission, but video signals were in the broadband range and this was a technology, then, under construction. (van de Nieuwe Giessen, 1996).

& Halske equipment. In the nineteen thirties it had decided to install automated Siemens & Halske equipment as the uniform basis-equipment for the Dutch telecommunication system. In this perspective it was no option for the Dutch telecommunication industry to challenge Siemens & Halske's head start in switching equipment, even not for large company as Philips.

Yet, in the societal time-frame shortly after the ending of World War II, it was obvious that business with Germany was inappropriate. Siemens' properties were regarded war-booty and NSF/Philips was the obvious partner to take over Siemens' licences, equipment and establishments. NSF/Philips started production of the Siemens F switching system in 1947. As it started the production of switching equipment, it changed the name 'NSF' into Philips Telecommunication Industry (PTI). PTI was divided in two groups. The Radio-Radar group covered a range of equipment from broadcasting equipment to radar, from portable radio-equipment to military and civilian equipment. The Telephone-Telegraph group entailed the production of telephone sets, transmission equipment, business-systems and public switching equipment.

PTI was successful in many fields of activity. It gained the largest market-share in switching equipment in the Netherlands (± 70%) next to Ericsson (± 15%) and NSEM (± 15%). In transmission equipment it was the main producer of equipment, amplifiers, measurements-tools, cables and carrier-wave systems. In end-user equipment it had a considerable share in telephone sets and it was the sole supplier of business-systems to PTT.

Many systems were exported to other countries like Argentina, Denmark, Spain, Norway, Poland, Australia, several African countries, Pakistan, India, Iceland, and several South-American countries, especially radio transmission equipment. PTI was also very successful in the development of mobile telecommunication equipment (Mobilophone) and the Netherlands was the first country to have full coverage with its mobile telecommunication network (cf. NEM, 1991)

With the increasing demand for telephony and the increasing capacity of the transmission system, the limits of the F-system were soon reached. The F-system lacked capacity and speed to handle a sufficient volume of telecommunication traffic within the same time. By 1952 PTI had developed its own version of a mechanical switch, able to handle 300 steps per second. Switching systems based on this AT technology were widely installed by Dutch PTT.

General technological developments

Two factors have pushed developments towards a new generation of switching equipment: the advent of computer-technology and digitalisation of transmission. The first computers were built with vacuum tubes and relays, which made the systems extremely large and expensive. However, they were in instant success because of their ability to handle complicated arithmetic problems. The use of transistors and semiconductors have made computers smaller, cheaper and faster, which has boosted the success of its introduction. The larger the number of computers, the greater the need for communication between computers. Yet, there is a marked difference between computer signals and voice signals. Computers communicate in binary bits, forming a digital signal, whereas voice communication is based on an analogue signal. The advantage of a digital signal is its improved efficiency and its much greater stability. The modulation of an analogue signal into a digital signal is done by Pulse Code Modulation (PCM), in fact an old technique developed in the late nineteen thirties, but only implemented when the components to build such equipment (transistors, semiconductors) were widely available and relatively cheap. The first digital lines were installed in 1972, relatively late compared to other countries.

Source: van Hilten, 1981; Hooijmans, 1981; de Jong and Tours, 1981; de Jong 1981

Box 22 *Converging technologies*

Despite a series of incremental improvements made to the AT switch, its life-span was only limited. Not only was there the increasing demand for speed and capacity, but technological developments were on the verge of breaking through, the latter especially induced by an increasing use of computers. This entailed a whole new type of demand, because computer-technology was based on binary bits, rather than the oscillation between frequencies of the analogue signals.
It is especially for these reasons (speed, capacity and digital signals) that from the mid-1960's onwards, many telecommunication industries have started experiments, not only to digitalise the transmission of signals, but also to digitalise the switching itself. However, the first attempts in switching were not very successful. The signal was weakened and distorted too much.

In line with developments abroad (especially in the USA), PTI decided to develop a semi-electronic switchboard (the PRX), which was clearly faster, more reliable and much cheaper than the classical electromechanical switch-boards. Simple ‘reed-relays[7]’ replaced the mechanical switching elements. A computer was attached to perform several managerial and accounting functions. This Stored Programme Control (SPC) system was a model of efficiency: much easier to produce, much smaller, lower energy consumption, insensitive to dust, temperature changes as well as insensitive to changing levels of humidity. Furthermore, the SPC systems hardly demanded any maintenance. Especially when PTI, in close cooperation with PTT, managed to control several switchboards from one location, it sowed the seed for a very successful introduction (van Hilten, 1981).

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[7] A reed-relay is a small component meant to establish a galvanic contact. The contact-points are made of reeds and enclosed in a thin glass-tube (very much like a filament in a lightbulb). The contact points are operated by a coil, surrounding this tube.

> In the 1950's, when telephony -like textiles and steel- was a conventional industry, development costs for an electro-mechanical exchange were around 10 million dollars, while expected life-cycle was about 25 years.
>
> By the late 1960's - early 1970's, when electronic-based analogue switching systems were being introduced into the public network, the system lifetime had dropped to between 12 and 15 years. But R&D costs had increased dramatically to 200 million dollars.
>
> The digital systems of the 1980's have an even shorter lifetime: between 8 and 12 years. Most significantly, R&D costs have rocketed to 1 billion dollars or more.
>
> To cover such phenomenally-high development costs, suppliers need a larger market in which to operate....certainly larger than their traditional markets.
>
> *Cor van der Klugt, President and chairman of the Board of Philips at the Holland day telecommunication forum, Geneva, October 1987*

Box 23 *Generations of technologies, their increasing costs and decreasing life-cycles*

In hindsight, the SPC switching systems were only a transitional stage in the development towards full-digital switch-boards. Yet, Philips was shocked by the massive costs of development. It seemed that the development of telecommunication switchboards was liable to the rule of ever increasing development-costs, while the life-span of equipment was ever shortening. To earn back the development cost of the PRX exchange, it needed to find new markets, but this was easier said than done. The European market for switching equipment was highly protected and the only thing that Philips could do was to look for new markets outside Europe. It seemed that these were to be found in Saudi Arabia, Malaysia and Indonesia. A consortium led by Philips, and with the participation of Ericsson, modernised the Saudi Arabian telecommunication system, which was a mega-deal (5 billion Dutch guilders), not just for Philips, but for the entire European (transmission) telecommunication industry. The deal did not just include switchboards, but also cables, amplifiers, modifiers, etc. A similar large agreement with Malaysia was shipwrecked in sight of the harbour, because Philips lacked the funds to pre-finance the deal. An agreement with Indonesia was cancelled for political reasons. This has made Philips rather shy towards the development of further technological innovations in fixed line telecommunication systems, especially switchboards. Further investments towards digital technology would be a too heavy burden if no new market was apparent. The extremely high costs of development could easily harm other branches of the Philips Telecommunications Industry.

Public switching technology was an important branch in the telecommunication industry, but PTI was active in many other fields in telecommunication and broadcasting. Next to the existing branches, PTI acquired Hollandse Signaal Apparaten (Dutch Signal Equipment) in 1956, to strengthen its position in defence systems and radar technology. PTI was also an important international supplier of broadcasting transmitters (TV and radio), radio-communication equipment, mobile radio-telephone equipment, base stations for mobile equipment, network equipment, and a range of transmission systems. Philips had also developed a range of products for aviation and shipping; fixed radar systems for traffic control and mobile systems to be used on ships and aero-planes (cf. NEM, 1991, van de Nieuwe Giessen, 1996). Thus, PTI had a substantial portfolio in international markets, especially in transmission equipment. Yet, the European market for switching equipment, was still too well protected to enter.

5.4.3 Ericsson and NSEM

The Netherlands telecommunication system has emanated from a patchwork of multiple suppliers, initially owned by private companies or municipalities, each with its own supplier. This has set the path for future developments, because each step along the path was already, more or less determined by former moves made in the past, and with each step was more difficult and more expensive to reverse the path. Most of the equipment in those early days was purchased from abroad, especially Siemens and Halske equipment from Germany, Ericsson from Sweden and Bell equipment (under several names) especially from the Belgian Bell subsidiary BTMC.

The Ericsson Telefoon Maatschappij (ETM) was founded in the Netherlands in 1920 as the first subsidiary of Swedish LM Ericsson. From its beginning it has been an important supplier of switching equipment as well as of telephone sets. The initial local structure of the telecommunication networks had given Ericsson a solid position in several major local networks.

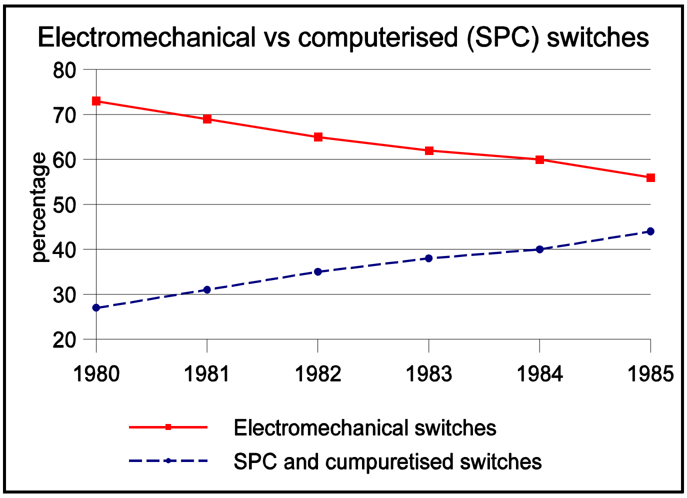

Figure 45 *Electromechanical versus computerised and Stored Programme Control switches*
Source: Wieland, 1988/PTT annual reports

Its solid position was especially due to the fact that is was the preferred supplier of the Rotterdam network, which stayed independent from Dutch PTT until the World War II. Ericsson has traditionally been one of the frontrunners in hardware development. It had for instance supplied the Rotterdam system with automated equipment already in the nineteen twenties, even before PTT took the decision to automate the whole Dutch telecommunication network.

A rather similar kind of story can be written for NSEM[8] (later Alcatel) and its predecessors. The company has been present from the first years of telephony in the local networks and it was the supplier of the The Hague network, which, just as the Amsterdam and Rotterdam network, stayed independent from Dutch PTT until World War II. Both Ericsson and NSEM have basically supplied technology off the shelf. The research capacity they had in the Netherlands could be typified as down-scaled replica's of the parent company. Their research departments managed the same line of products as the parent company, with only small amounts of product- and process-adjustments to the extent deemed necessary (Chesnais, 1992, p.

[8] NSEM: Nederlandsche Standard Electric Maatschappij

272).

Ericsson has been an important company in the Dutch telecommunication system, a position it largely owned to its modernity. It was one of the first to automate its switchboard functions in the nineteen twenties, and it was also the first to introduce the Store Programme Control switchboards in the Dutch telecommunication network in 1971. It took PTI and PTT another three years before the first Philips PRX SPC-exchange could be installed in 1974. However, from that moment on growth of the SPC switchboards was unstoppable. PTT decided in 1977 to purchase SPC equipment from just two suppliers. PTI was the preferred supplier (to the amount of 70% of all switchboards) and Ericsson was the second supplier (the rest 30%). NSEM, which traditionally held a market share of 15% was excluded. Yet, it was granted a range of compensation orders for telephones and business-systems, however only after it had filed complaints about its exclusion in Parliament.

5.4.4 Cooperation in post-war telecommunication research

The construction of public buildings used to be the responsibility of the Rijksgebouwen Dienst (State Building Service). However, contrary to common practice, the new PTT laboratory in Leidschendam was designed by van der Embden, the same architect who had designed the laboratories for Philips Telecommunication Industries (PTI) in Hilversum

(van der Nieuwe Giessen, 1996).

Box 24 *Philips as a 'role model' for PTT*

Philips and PTT have most obvious been the two main actors in the Dutch system of telecommunication research. The organizational setup of Philips research organisation has clearly been a bench-mark for the PTT research organisation, not only in its initial ambition to perform basic research, but also in the organizational setup and even in the building of a new laboratory (see text box).

Ambitious indeed were the initial objectives of the Central Laboratory. In the words of PTT's then acting director, dr. Neher, the aim of the Central Laboratory was 'to be active in the field of research and to bring new findings to a basic solution for application.' The emphasis was rather on research than on development. The initial organizational profile of the Central Laboratory reflected these high ambitions, as it had placed the physics lab and the chemical lab at the core of the research organisation, surrounded by several application labs. However, soon after PTT had to acknowledge that its ambition level were chosen too high. Fundamental research did not belong to PTT's research portfolio and even applied research was only performed at a modest level. The most important research activities were organised in the field of system-development (Hooijmans, 1981, pp.107-8). This was well reflected in the mission statement as it was published in 1973. The objective of R&D activities was 'to acquire knowledge and skills in order to advise the company in the realization of its company goals and to support technological-scientific innovation as well as technological-managerial innovations'. Here the emphasis was more on development, rather than on research. This 'down to earth' movement has been the leading adage, even in the first years of the Central Laboratory, even though the official motto was far more ambitious. But still, the Philips research organisation, especially its famous NatLab has been a source of inspiration for the PTT research organisation, as well as a source of envy.

Indeed, there were reasons for envy! Philips Natlab had already developed a high reputation in scientific circles soon after its foundation in 1914. Its founder, professor van Holst, applied the principle that young researchers, 'who were willing to cross the borders of their scientific domain and were willing to keep in tough with scientific developments, should have the freedom to explore', and this is exactly what Philips researchers did. The NatLab was a relative refuge within the company where there was room for interesting ideas and lively discussion, and where basic research could proceed for many years in a relative sheltered environment. NatLab researchers indeed had a good reputation in scientific circles and they were respected guests in international conferences and research-centres, such as the research laboratories of AT&T (Bell laboratories) and IBM. Especially the many trips that the Philips researchers made to the US have been a source of inspiration, because the US was on the average ten years ahead in many technologies during the 1950's. The NatLab researchers were often among the first to become acquainted with new technologies, new trends, new materials in electronics, optics and the like. But the researchers were not just 'on the move' to acquire knowledge; they also had a high production of new knowledge and inventions. Philip's NatLab was very active in filing new patents and throughout the years its patent portfolio developed into a most precious commodity, especially precious in the exchange of patents with other knowledge-intensive companies. Cross-licencing provided a relative easy opportunity to acquire new knowledge. But licence-fees have also been an important source of income; approximately 1 billion guilder annually in the early 1990's (cf. Metze, 1991, p.141).

Yet, Philips may have been strong in the production and acquisition of knowledge, it was rather slow in adaptation and implementation of new technologies. Philips has been a true model of the science-driven, sequential innovation approach, a step-by-step approach with lots of discussions every time that the ball was handed over to the next player in line. It lacked team-spirit and was rather slow in the implementation of innovations. This has been the case in many technological fields. We will briefly highlight the case of computer-technology as it serves as an example for the extraordinary position of the NatLab in the Philips organisation, as well as it is an example for the difficulty to cooperate between two, more or less, related departments.

> It goes without saying that Philips in the 1950's had the best cards in the Netherlands to step into computer technology. It had the knowledge, skills, size and funds to enter this new technology successfully, however, it initially refrained from it. The reason was that Philips had developed strength in two fields: consumer electronics and components. Each field demanded a different strategy. In consumer-electronics it was basically a competitor of many other firms active in the same field, whereas in the field of components, it was rather the relation of a supplier to a user, more partner-like. The advent of computer technology was an excellent opportunity to profile itself in the latter field. It stepped into an exclusive agreement with IBM to be the preferred supplier of a guaranteed amount of computer components. In exchange Philips would refrain from the commercialisation of computer systems. Philips kept its side of the deal, despite severe pressure from the Dutch science community to participate in Dutch attempts to development a genuine Dutch computer industry
>
> Advancement in computer technology had a strong radiation in those days. It was a symbol for the spirit of strength and modernity that has been an important driving force in the post-war reconstruction of the Netherlands. The performance of the Dutch computer-science community had placed the country among the fifteen countries that pioneered on the leading edge of computer-technology (van Oost and van Hoorn, 1998).
>
> The Mathematical Centre had already built its first electronic calculator ARRA in 1951. Later it built an improved version, the ARMAC. Also PTT's Central Laboratory was involved in computer development. Its first electromechanical machine, ZERO was built in 1952 and was soon followed by improved versions such as the PTERA and ZEBRA. Business (insurance and banking), industry (aircraft construction), and the scientific community were very much interested, but PTT as well as the Mathematical Centre were of the opinion that production was not on their way. Both organisations invited Philips to take their design in production, but Philips refused in both instances, not to jeopardise its deal with IBM. However, it is also very likely that the 'not invented here syndrom' of the Philips researchers has influenced this decision.

The first computer-technologists had a zest for acronyms. The first computer ENIAC stood for: *Electronic Numerical Integrator and Computer* and EDSAC, the first fully electronic machine based on the 'stored programme' architecture, stood for *Electronic Delay Storage Automatic Calculator.*
This tradition was also adopted by Dutch computer scientists. Here are some examples of Dutch computers and their names in Dutch and English (between brackets).

ARCO 1947	Automatische Relais Calculator voor Optische Berekeningen *(Automatic Relay Calculator for Optical Computation)*
ARRA 1951	Automatisch Relais Rekenmachine Amsterdam *(Automatic Relay Calculator Amsterdam)*
PTERA 1953	PTT Electronische Rekenautomaat *(PTT Electronic Calculator)*
ZEBRA 1957	Zeer Eenvoudige Binaire Reken Automaat *(Very Simple Binary Calculator)*
PETER 1956	Philips Experimentele Tweetallige Electronische Rekenmachine *(Philips Binary Electronic Calulator)*
PASCAL 1960	Philips Akelig Snelle Calculator *(Philips incredibly Fast Calculator*

Box 25 *Abbreviations in early computer design*

The Mathematical Centre thereupon decided to found a company 'Electrologica' for the commercialisation of its computer technology. Between 1956 and 1958 it developed the X1, a fully transistorised computer. PTT went abroad, and found the British firm STANTEC (Standard Telephones and Cables) willing to commercialise its computer design.

In those same years, even though the board of directors had decided not to step into computers, Philips NatLab researchers started their own experiments in computers, heedful to NatLab founder's adage that researchers should have the freedom to explore. In 1956 they built their first computer, a small, yet rather fast calculator, however, not very reliable.(A cardboard plate hung next to the machine with the equivocal warning 'Don't count on it!') The experience gained with this machine was used to be the starting-point for a new design, an improved and more accurate version of the old one. In the course of the project the initial concept was altered several times and it finally became one of the fastest machines world-wide. The machine was only used for NatLab's scientific calculations and was named Pascal

Computers were back on Philips' agenda when IBM broke the rules of the agreement and decided to build its own component-factory in the early 1960's. Philips board of directors still decided to step into computers, albeit, much later than most of its competitors, and founded the Philips Computer Industry (PCI). The newly found computer branch could build on the knowledge and know-how developed at its NatLab in previous years and several members of the NatLab research team were transferred to set up the Philips Computer Industry. The computer-group at NatLab was thus thinned out and only in 1969 it started to recruit several young scientists. However, the relations between NatLab and PCI researchers was flagging. NatLab researchers were of the opinion that PCI researchers showed insufficient interest in NatLab's basic research efforts, while PCI researchers found that NatLab researchers showed no interest whatsoever in the development-problems they were struggling with. NatLab researchers felt no responsibility to work with existing technology, because practical application of basic technology was not 'their cup of tea' (cf. van Oost, 1998, pp. 290-7).

The case of computer technology is revealing for several reasons. First it has demonstrated the international scope of the Philips organisation. Managerial decisions to step into, or to refrain from a certain technology, were not so much influenced by national as well as by international considerations. Philips' 'deal' with IBM is a clear example. Similar 'deals' were for instance made with Sony and Matsushita in the case of VCR's. Second, NatLab had gained a rather independent position within the Philips organisation, allowing itself the freedom to research promising technologies, even in fields that the board of directors had decided not to exploit. Third, the NatLab suffered from the 'not-invented-here syndrom'. No technology developed by others could ever meet the high standards of the NatLab researchers. Fourth, NatLab's frame of reference was much stronger influenced by the (international) scientific community, than by the market. As a result, the renowned NatLab developed into a rather isolated unit, sheltered from market fluctuations, but highly valued in scientific circles.

It goes without saying that the links between basic research, and the next stages of development were rather weak. That was not only the case in computer-technology, but also in telecommunication, consumer electronics and other branches. The NatLab researchers had an almost untouchable position within the organisation, not only because they stood at the cradle of many successful products, but also because they provided the firm with one of its most important assets, the patents. Vertical cooperation between the research department and the product branches was weak at Philips, but unfortunately, so was the horizontal cooperation between related branches. The Philips branch for computers PCI and its branch for telecommunication PTI were both involved in computer technology, but there was no cooperation whatsoever. At the same time that PCI was developing its P-1000 mainframe computer, the telecommunication branch (PTI) had the DS-714 switchboard under construction, which was especially designed for the collection and distribution of weather-forecast messages to be used in aviation. The initial version of this machine only included few computerised elements, but gradually the computer was put at the heart of the machine. The PTI researchers developed the whole computer, even its smallest elements under their own control. The market for this type of machinery was rather small and cooperation with other knowledgeable departments would have been a keen option to keep development-costs low. Cooperation between PCI and PTI could have provided that option, but an exchange of ideas, know-how and technology was never even tried, even though the distance between the two laboratories was less than an hour's drive. PTI's DS-714 was developed in the 1960's and commercialised until the late 1980's. However, PTI has never made any profit with this machine, because half of the price was needed to cover the costs of development. A common way in Philips to soften financial setbacks was to claim that it had learned so much of the process, which could be used in related products. However, it hardly ever reached that point because organizational fragmentation in Philips avoided such vertical or horizontal cooperation (Metze, 1991, pp. 141-6).

The high scientific reputation of the NatLab has been an important frame of reference for the initial setup of the PTT's Central Laboratory, and indeed there were several similarities between both Philips and PTT. Philips was on the leading edge in many technologies, and so was PTT, especially in radio technology and transmission. Philips and PTT were both active in radio-transmission, however, in non-competing areas. Philips was especially interested in broadcasting (point to multi-point transmission), whereas PTT's interests were in the field of point-to-point communication.

However, the technological and scientific problems in both fields were rather similar and researchers in both fields regarded each other rather as peers than as competitors. Inter-organizational cooperation used to be stronger than intra-firm cooperation. This was strongly facilitated by the fact that both Philips and PTT engineers belonged to a small 'elite' of telecom-engineers, who shared the same background, education, language, etc.

The same situation was to be found in the field of transmission technology. PTT struggled with a range of problems in transmission and ready-made solutions were not available. PTT was active in research, but was not intending to step into large scale production. This was regarded to be a task of industry and Philips was thought to be the best suited partner. Yet, at the state of technology, the only way to find the right criteria for equipment development was in close cooperation between the researchers of both companies. Many new technologies could be developed to a large extent from the drawing board, but the proof of effectiveness was in the field, under real-life circumstances. The existing network offered that opportunity and researchers of both organisations were used to visit each other and to work shoulder-to-shoulder in the same projects. Close cooperation between development departments has been a precondition for an effective industrial design and both organisations have benefited from such close cooperation. Thus, there were similarities in orientation and technological fields and there were mutual independencies, not in the least because PTT had developed into an important customer. It furthermore, provided Philips with the opportunity to acquire knowledge that also could be used and commercialised in other countries where Philips was present.

However, next to the similarities between the two companies, there were also many differences. Philips was a large, multinational and multi-faced company and active in a range of branches, technologies and products, whereas PTT was more inclined toward a single technology. Furthermore, Philips was involved in all the phases of innovation: basic research as well as applied research, product development, quality control, standardisation, marketing and sales, whereas PTT was especially active in development, implementation and exploitation. This made the distance between development and the actual use of a new technology rather short in PTT.

Cooperation between PTT and Philips especially concentrated in Philips telecommunication branch PTI. Before the war it concentrated in relative simple transmission technologies such as cables and amplifiers, but gradually the variety of technologies increased and after the war there was a range of products where PTT and PTI cooperated such as radio transmission, broadcasting transmitters and receivers, radiotelephones, and a range of modulation technologies. Both companies were also active in broadband technologies, especially in transmission of television signals.

Despite differences between the companies, cooperation between PTT and Philips was most attractive. For PTT it was especially attractive because Philips was capable to invest heavily in research activities, while PTT was curtailed by government's counter cyclical policies. The extension of its telecommunication network trailed behind demand and long waiting lists for a telephone connection were daily practice in the 1950's and 1960's. The only way to get the utmost of the existing network was to innovate in transmission capacity and a rich innovation partner was a good option in that context. The attraction was, however, based on mutual interests. Philips could benefit because PTT offered the right circumstances to test equipment under real-life circumstances.

5.4.5 Structure of post-war telecommunication research

The call for reconstruction and modernisation in telecommunication has been as strong as in other societal and industrial sectors. Both reconstruction and modernisation were regarded to be instrumental to the process leading towards industrialisation. The better the infrastructure, the more business-opportunities. Ambitions at PTT were high, but money was low. The first years after the war PTT was strongly supported, because government granted large subsidies for investments. However, as soon as government budget were exhausted by international crisis or by its counter cyclical policy, it had an immediate and short-time effect on PTT's financial position. This was especially the case between 1959 - 1965, when government curtailed the investments of PTT, as part of a general reduction of public expenditure (Ottenheim, 1974). This seemingly arbitrary system of financial decisions has forced PTT more than once to cancel orders.

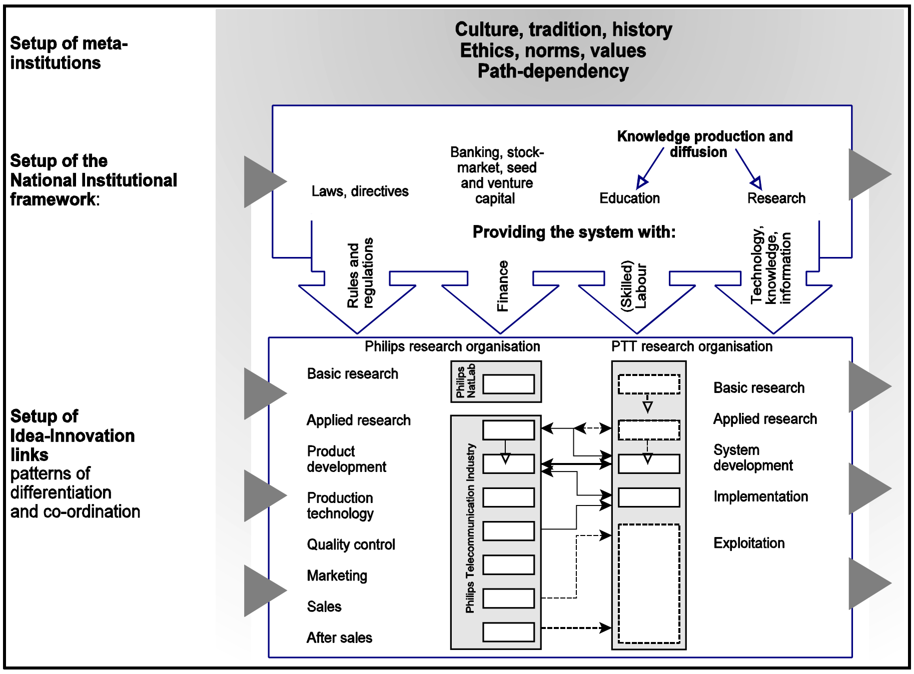

Figure 46 *Structure of research activities between Philips (Philips Telecommunication industries) and PTT*
(Uninterrupted line, strong cooperation; interrupted line, moderate cooperation)

Thus, even though the general economy developed most prosperously - Le Miracle Hollandais (van den Brink 1984)- PTT was on the constant verge of lagging behind. Using demand as an indicator for its backlog, we can observe that PTT's waiting list for telephone connections increased from 65,000 in 1962 to 155,000 in 1965. The development of the telecommunication sector between 1950 and 1970, can be characterised as growth under constraints.

The system of rules and regulation has granted PTT the de facto monopoly for telecommunication services, but it also restricted PTT in its own economical development. The system of regulation and finance was aiming at short-term developments, while the investment decisions regarding transmission and switching systems demanded a much larger time-scope. PTT has managed to negotiate a longer term perspective for its investment plans, but it could not develop in the same way as a market-based company would have done. This particular situation has forced PTT and PTI towards close cooperation. PTI was thus very much dependent on PTT. Mutual dependence was especially high in switching equipment, because the European market was still well protected by individual countries, and PTI's sole customer for switching equipment was Dutch PTT.

Yet, there were also technical reasons that PTT and PTI acted like hand in glove. The problems both companies faced were rather identical. Furthermore, PTT offered the opportunity to experiment new technologies under real-life circumstances, which was a mutual beneficial strategy.

Restricted growth has pushed both companies to get the utmost of existing technologies. There was a strong drive in both companies to increase the number of channels on the same telecommunication line and time and time again, they managed to increase the network's capacity.

As a result, cooperation was strong, especially horizontally between both companies in area of product-development (on the PTI side) and system-development (on the PTT side). In other areas the cooperation was far less strong. There was indeed cooperation in the areas of applied research, but this was only a remote activity, subservient to the field of product- and system-development. The same is true for the implementation of innovations in the network, because the proof of the pudding is in the eating. Thus, relations were strongest in the development of new equipment and their implementation in the network.

5.5 Telecom and agricultural clusters compared

Do national-sectoral systems of innovation exist? Are they a reality and do they matter? Based on the historical journey we made in the last two chapters, the answer is confirmative beyond any doubt. We have extended the tables that we introduced in chapter 4 with an additional column for the nineteen seventies. It is remarkable to see that the differences that we already found in chapter 4 are largely consistent over time.

		Telecommunication			Agriculture/food & chemistry cluster		
		1910	1940	1970	1910	1940	1970
Technology	*Type of innovations*	*incre-mental*	*incre-mental*	*incre-mental*	*incre-mental artisanal progres-sive*	*incre-mental artisanal progres-sive*	*incre-mental artisanal progres-sive*
	Scope	*local*	*national*	*national*	*regional (inter-) national*	*(inter-) national*	*inter-national*
	Leader or follower	*follower*	*follower*	*follower*	*leader*	*leader*	*leader*

Table 32a *Technology: The telecom and biotech sector compared (1900 - 1970)*

Telecommunication was predominantly subservient to economic development. Its role was to provide the infrastructure and the services, but the sector was not seen as an economic sector with a growth potential and dynamism of its own. This was a marked difference with the agriculture/food/chemical cluster. This cluster was rather a spearhead of economic development, and that is why there were numerous institutional arrangements to improve its economic performance. The post-war period has reinforced and strengthened the institutional structures for which the groundwork was already laid in the pre-war period. The highly integrated system of research, information/advice, and training/education was further developed in an encompassing expert-system, which gave direction and meaning to agricultural development. Dissemination, transfer and implementation of knowledge formed the backbone of agricultural R&D. Dissemination of knowledge was strongly adjusted to local conditions. Education and information were also tailored to meet the specific requirements of the local eco- and production system, but also to meet the requirements of the local social system. Thus, the R&D system in agriculture was de-centralized in local actor-networks. Innovativeness was highly valued and the general adage was to increase scale and productivity in the sector. The scope of the agro/food/chemistry cluster was international, strongly oriented towards growth through exports, whereas the scope of the telecommunication sector was predominantly limited to the national borders.

Despite the highly sophisticated technology that was used in telecommunication, the Dutch telecom industry was predominantly a technology-follower. Innovativeness was oriented toward improvement of already existing concepts, which were mainly developed in the large telecom laboratories abroad. Especially the telecommunication laboratories of Bell and Nortel were involved in pioneering research in transmission and switching. The technologies that PTT and Philips developed and introduced in the network were basically variations on existing USA concepts. This was a marked difference with the agriculture/food/chemistry cluster. Innovativeness in the sector was particularly high and multi-faced. Incremental innovations were found next to progressive innovations. But individual farmers and breeders have also strongly contributed, especially with artisanal innovations.

			Telecommunication			Agriculture/food & chemistry cluster		
			1910	**1940**	**1970**	**1910**	**1940**	**1970**
Organizational architecture of the idea-innovation chain	*Differentiation*	*vertical*	*low*	*relatively low*	*relatively low*	*low*	*low*	*low*
		horizontal	*low*	*relatively low*	*relatively low*	*low*	*low*	*low*
	Division of labour		*low*	*relatively low*	*relatively low*	*low*	*low*	*low*
	Mutual dependency		*linear*	*linear*	*linear*	*flexible*	*flexible*	*flexible*
	Coordination	*within the company*	*hierarchy*	*hierarchy*	*hierarchy*	*hierarchy*	*hierarchy*	*hierarchy network*
		between companies	*market*	*hierarchy*	*hierarchy*	*networks*	*networks*	*networks*
		Mobility of workers	*low*	*low*	*low*	*low*	*low*	*low*
		Mobility of staff & management	*low*	*low*	*low*	*considerable*	*considerable*	*considerable*

Table 32b *The organizational architecture: The telecom and biotech sector compared (1900 - 1970)*

Organizational behaviour in the two sectors under review was strongly dominated by the structure of the sector. In telecommunication we find few large companies, whereas in the agriculture/food/chemistry cluster we find some large, as well as numerous small companies. The setup of the idea-innovation chain in the large companies was mainly based on a linear setup of rather specialised activities, with only few links between the subsequent steps. This was a marked difference with the numerous small companies (especially in agriculture) which had no division of labour whatsoever. Research, production and distribution activities, was usually carried out by the farmer/breeder her/himself. This was a much more flexible setup, easily adjusting to changing circumstances, and strongly embedded in the institutional structure of the OVO triptych. Networking, and a high degree of integration between the organizational and institutional dimension was key in the agriculture/food/chemistry cluster.

Coordination in the telecommunication sector was basically organised between hierarchies. Philips, with its subsidiary PTI was organised as a vertically integrated firm with bureaucratic administrative control structures. Coordination was organised within the hierarchy of the firm. The biggest difference between the telecom operator and the telecom industry was that the industry was basically oriented towards profit maximisation, while the operator was constrained within a complex system of societal ties, in which it had exclusive right to offer telecommunication services to the public, but was restrained in its expansion by government interference. However, the difference between operator and industry was not as big as it may seem. The peculiarities of the telecom operator, including its inefficiency, were accepted by a broad range of societal groups, which Noam (1987, p. 32) addressed as the postal-industrial complex. This involved a tight system of relations between government, parliament, telecom operator, domestic suppliers of telecommunication equipment, residential users, the newspaper industry and the labour unions, who were all involved in a rent-seeking coalition of mutual benefits. The exclusive position of PTT was acknowledge on the condition that all other stakeholders were allowed to share in the revenues from its services. This cartel-like system was profitable for the insiders and its inefficiencies were largely hidden by the general downward trend in the cost of electronic technology. Thus, industry and operator were like hand in glove and often operated like one system.

Whereas relations in telecommunication were basically coordinated within the hierarchy of the industry and the operator, in the agro-industrial cluster the relations were rather coordinated by the dense, maze-like structure of numerous networks and associations. Farmers as well as suppliers coordinated part of their relations in open markets, but at the same time they are also involved in, and constrained by a range of networks and social obligations. Furthermore, the social ties, especially those of religion and church, were still rather strong in the post-war years. Many social organisations were rooted in the traditions of power-sharing and joint decision making, as in the agricultural co-operatives. The co-operative allowed farmers access to means of production, and control over a range of important resources. The statutory agricultural organisation (PBO) is in some respects, a logical variation on the cooperation. It provides the sector with a system to adjust individual and collective interests in a balanced way. Many agro-industrial co-operations have developed into large scale agro-industrial complexes with extremely strong market-positions. The actors in this system are mutually connected through a range of mutual ties.

			Telecommunication			***Agriculture/food & chemistry cluster***		
			1910	***1940***	***1970***	***1910***	***1940***	***1970***
Institutional environment	*Social embeddedness*		*narrow*	*narrow*	*narrow*	*broad*	*broad*	*broad*
	'Supply' of skilled labour		*sufficient*	*sufficient*	*sufficient*	*sufficient*	*sufficient*	*sufficient*
	Education		*in company*	*in company*	*in company*	*in sector*	*in sector*	*in sector*
	Research funding		*n.a.*	*public*	*public & private*	*public/ private*	*public/ private*	*public/ private*
	Impact of regulations		*conside-rable*	*high*	*high*	*moderate*	*moderate*	*increasing*
	Role of associations	*training/ education*	*none*	*none*	*minor*	*major*	*major*	*major*
		finance	*none*	*none*	*none*	*conside-rable*	*conside-rable*	*conside-rable*
		regulation	*none*	*none*	*none*	*low*	*increasing*	*conside-rable*

Table 32c *The institutional environment: The telecom and biotech sector compared (1900 - 1970)*

The close knit of the agro-industrial cluster is visible in economic relations, but is similarly strong in societal relations. In chapter four we already discussed the provision of money for extension or modernization of a farm. An application for a loan at a Raiffeisenbank or Boerenleenbank (both cooperatives) was discussed in the board of the local establishment. The board was chosen by the members of the bank, especially local farmers. Reputation of the applicant was involved in decision-making, but so was the reputation of the board. Trust, confidentiality, loyalty and reliability were at stake in the process of decision making. Distrust, or a hidden agenda could seriously harm the position of a board-member in the local community. Another example is the role of the farmers' union or 'Boerenbond'. These organisations had particularly strong positions in the local community. It was for instance no exception that members of the Boerenbond were second examiners in agricultural schools.

Innovativeness in a sector can be enhanced by an unobstructed flow of knowledge. An engineer who starts a job in a new company will bring his/her own perspectives, viewpoints and experience into a new context. Mobility in a sector can boost innovativeness, because it allows a free flow of knowledge between the actors.

The organisations of local farmers often gave their co-operative an inspiring name, which usually is a strong expression of the values that underlie such initiatives.*'De Eendracht'* (Unity) is a clear example of the adage *United we stand, divided we fall!*
Other inspiring names were (translations between brackets:

- *De Combinatie* (The Combination)
- *Union*
- *Phoenix*
- *De Vrijheid* (Freedom)
- *Eureka*
- *De toekomst* (The Future)
- *Onder ons* (Among Us)
- *De Centrale*

No doubt the most poetic name is *l'Esperance* (The Expectation)

Box 26 *The inspiration of names*

The duration of labour-contracts in the post-war telecommunication sector was usually very long. Starting a career at an employer almost automatically implied life-long employment by that same employer. This was particularly strong at PTT. It had its own education programmes for technicians, its own brass-band, its own sports club and its own holiday camps. Working at PTT was belonging to the PTT family, also taking its social norms and values. This was especially the case for PTT researchers. A common career for a graduate student was to start in research and learn every trick of the trade. The next career-step usually was a position as an executive or manager. Only few engineers left to find a job outside PTT and even less outside the telecom sector.

At face value this also seems to be the case in the agro-industrial cluster. Farmers do not move so easily and the degree of specialization is often such that agricultural engineers stick to their own field of expertise. However, there are also some important exceptions. Many agro-industries have started as co-operatives. The production of dairy products, starch, sugar, trade in corn and most of the meat-industries have started as co-operatives of local farmers/breeders. Many co-operatives, active within the same field have established new co-operatives to perform administrative tasks, research and quality control. Most of these co-operatives with highly specific tasks had a clear preference to recruit management personnel from outside their own circles. A co-operative head-hunt agency assisted in these processes. These constructs, which were designed to avoid a conflict of interest, provided a good channel for the exchange of knowledge. This pattern was also visible in the enforcement structure, which highly valued an independent position towards farmers and the industry. Therefore, inspectors were not permanently assigned to one region, but were circulated over several regions (cf. Oosterwijk, 1999, p. 45). This pattern of 'outsiders-supervision' provided an easy exchange of knowledge and information in the innovation system.

The patterns that we found in the technological orientation, the organizational architecture, the institutional environment, the sector characteristics have been remarkable persistent over time. The changes in the organizational structure and institutional environment are only small and mainly concentrate around a gradually changing role of government.

The role of government has indeed gained importance over the years. This was already visible in the nineteen thirties when government took a much more active role in the economy than it was used to do before. Yet, in the post-war years, government took the lead in formulating the goals for the economy, not only because it was a keen strategy to restore the country after the devastations of the war, but -even more- because it was convinced that strong government could manoeuvre the 'ship-of state' through the shoals and cliffs of a purely market-based economy. Planning was the key-word in this new attitude and government has strongly interfered in societal and economic relations which, until then, used to be the sole domains of individual citizens, in their role of customers, employees, businessmen or employers. The state gained importance over the market and government actively interfered in prices, wages, investment plans, sectoral development, and so forth. In telecommunication it has led to the development of a sheltered market, which allowed Philips to set up a viable production line for advanced telecommunication equipment. In agriculture we can basically observe the same pattern. Market prices of agricultural production were gradually replaced by a system of guaranteed prices, to enable farmers to set up a viable farm, and to contribute actively to the production of foods. Along with the new, central role of government in the economy, came the interference of government in the management of farms. New rules and regulations were designed and enforced, an extensive system of subsidies and levies was introduced for several products, investments and technologies, and farmers and breeders were overwhelmed with information and advice.

		Telecommunication			***Agriculture/food & chemistry cluster***		
		1910	***1940***	***1970***	***1910***	***1940***	***1970***
Sector characteristics	*Economic orientation*	*public service*	*public service*	*public service*	*growth*	*growth*	*growth*
	Market	*open*	*open*	*sheltered*	*open*	*open*	*open*
	Players in the market	*few*	*few*	*few*	*numerous*	*numerous*	*numerous*
	External relations	*few*	*few*	*few*	*numerous*	*numerous*	*numerous*
	Pattern of specialization	*trans-mission*	*trans-mission*	*trans-mission*	*high volume/ low prices*	*high volume/ low prices*	*high volume/ low prices*

Table 32d *Sector characteristics: The telecom and biotech sector compared (1900 - 1970)*

It is interesting to see that despite the different kind of dynamism in both sectors, the basic characteristics of sectoral specialization remained the same. The agricultural sector has strongly promoted productivity, and the result was a seemingly ever increasing yield per acre. It strengthened the general trade policy which was more oriented towards high production volumes at low prices, than at variety and quality. In telecom we found that PTT's initial specialization pattern in transmission technology, system development and network-management did not changed, even though PTT had to cope with several difficult problems, especially in switching-technology. Immediate after the war it was cut-off of its preferred supplier and it was quite a long shot to trust Philips' abilities to provide a sufficient supply of switching equipment in the long run. Philips may have used the initial Siemens technology, but still it was an unfamiliar technology for Philips. Several alternatives could have been considered. An option could have been to purchase equipment from abroad, or to bring research and production of switching technology under the responsibility of PTT. The latter possibility was not seriously considered. Production was a task for industry, not for the operator. This is a persistent pattern. Similar decisions were later taken in other technological field and the general policy was to licence PTT-patents for free to the Dutch industry. Purchasing equipment from abroad was also rejected. Firstly, because a lop-sided dependence from other countries was not very desirable, and secondly, because a genuine Dutch telecommunication industry strongly contributed to overall employment.

Despite the differences between the two sectors, in hindsight one can see that the research structure in agriculture and telecommunication have both developed impressively, yet, that the orientation and connectedness of relations were different. The research structure in agriculture was closely interwoven in the structure of societal relations, which were based on the traditions of power sharing, and which stressed the interdependence of private and public actors. The origins of this negotiated or corporatist framework lie in the post-war settlement between government, business and branch-organization, in which class-wide consensus exists about the process towards reconstruction, industrialisation and modernisation. A broad consensus towards Keynesian demand management, in which government, business and labour (unions) had committed themselves to the national goals of full employment, steady economic growth and the development of the welfare state. Important general instruments to accomplish these objectives were legally enforced price-controls measures and a central guided wage-policy to keep the domestic production costs significantly lower than its foreign competitors and which advanced the country's position in international trade (van den Brink, 1990). In agriculture this was implemented as a fair income for farmers, established through a system of guaranteed prices.

The telecommunication sector was not allowed to exploit its technology at the cross-roads of demand and supply; PTT was primarily seen as a governmental utility service and it fell under the same restrictions as other public services. Thus, even though both sectors have developed an extensive research structure, the limitations for telecommunication were much stronger than in agriculture. In telecommunication the research pattern specialised in network management and system development, and not so much in products that could easily be commercialised. In agriculture however, the pattern was very broad and covered all the steps in the idea innovation chain. This extensive and highly specialised system of research can be regarded to be the springboard for the giant leap towards research in modern biotechnology.

Chapter 6 Telecommunication under the change of the technological paradigm

6.1 Introduction

The post-war years have been a latency-period for several new technologies. Important discoveries and inventions, already made in the nineteen forties, could only break through in the nineteen seventies or even later. Take the example of the computer. The first ENIAC computer was already built in 1946. Its potential was soon recognised in scientific circles and several scientists put up the gauntlet to improve and surpass its performance. However, computer technology remained the exclusive domain of science throughout the nineteen fifties. In the nineteen sixties it could break through in the office environment. It took however, another twenty years before the computer could break through in the private market. Thus, between its first invention and the wide diffusion into private households, there were almost thirty-five years. If we trace what has triggered the break-trough, we find two important additional innovations in adjacent domains that have served as a catalyst for developments in computer-technology. First, there was the invention of the transistor, which basically held the same potential as a vacuum-tube, but it was more economical in the sense of energy consumption, much smaller, impervious to climate conditions, but above all: much cheaper than the classical vacuum-tube! The innovation of integrated circuits, which combined the function of several transistors on one silicium-chip, allowed the computer-industry to miniaturise the bulky mainframe systems into much smaller equipment. Increasing capacity, fewer components and lower prices have been ongoing processes in the computer industry. According to Moore's law, the capacity and performance of a computer doubled every 18 months. Whether it was an expert opinion or a self-fulfilling prophecy, Moores law has been an axiom for many years, and has proven to be true (Leyden, 1997).

The second innovation to trigger the rapid diffusion of computers to business and private households, was the computer-industry's agreement to use the same disc-operating-system, better known as DOS. This standard allowed for an exchange of information between computers. Thus, miniaturization, a standard operating system and an acceptable price level opened the doors for a successful commercialisation of computers.

The example of computer-technology does not stand on its own. Many discoveries and basic inventions have needed additional innovations in adjacent fields, to serve as a catalyst and expose the potential of the innovation to the full extent. Computer-technology itself has often triggered leapfrogging developments in other technologies. That has also been the case in the telecommunication sector. The most crucial technological innovations were triggered by the use of computer-based transmission technology and the use of computer-power to improve to improve switching performance. It finally ended that the classical analogue, electromechanical systems were replaced by fully digitalised systems.

However, these mergers of technology did not take place overnight. The potential of computer-technology was initially just recognised to perform managerial routine operations in the telecommunication system, but, already in 1969, the telecom engineers of the Bell and Northern Electric laboratories envisaged that the conversion of analogue speech into digital computer code would be a cost-effective way to improve the future switching performance in telecommunication. These two laboratories took the technological lead towards digitalisation, often in close cooperation. Already in 1972 Nortel engineers managed to squeeze a code/decode (CODEC) single translation unit onto one microchip, making it cost effective to convert analogue to digital and back again. These laboratories had also taken up initial work on digital switching technology. In 1975 Northern Electric had its first digital switches operational in its SL-1 business system, and in 1979 it launched the DMS-100, a full-featured local/toll digital switch to be used in the public network.

This new combination of telecommunication and computer technology was, in Schumpeter's terms, a true act of creative destruction. No matter the degree of sophistication in analogue transmission and electromechanical switching, digitalisation has virtually outdated analogue technology in one blow. It goes without saying that this paradigm-shift had far reaching consequences for telecommunication research. The core of research until the nineteen seventies was the relative simple world of analogue, narrowband telephony, with research themes as real-time, two-way communication, switching and addressing, and billing and security. Digitalisation has extended the research themes, for instance to themes like broadband transmission or how to add intelligence to the network. As a result the neatly arranged world of voice-communication (telephony), converged with the dynamic world of computer technology (data-transmission, Internet, E-mail, E-commerce, etc.) and the world of multi-media (broadcasting, video, radio, TV). The tendency today is towards new communication systems whereby a range of two-way services is offered in integrated service packages.

Digitalisation has thus affected virtually every aspect of telecommunication, whether in hardware (switching, end-user and transmission equipment) middleware (standards that serve as a backbone for specialised services, e.g. financial transactions) or software (end-user services). On the platform of digital design a range of new products emerged. It has freed the telecommunication system from its analogue constraints, but has also led to a dissolution of all prevailing notions. Until the nineteen seventies the term telecommunication mainly referred to voice-communications (telephony), but telecommunication today refers to a much broader system, encompassing the infrastructure as well as the services. The text-box opposite provides an overview of some new services, but it is just a selection. Telecommunication today is the container for one- and two-way systems of communication and involves a range of specialised equipment and services. To prevent us from losing track in the dynamism of the telecommunication sector, we will broadly follow the functional arrangement which was proposed by TNO/STB (1993):

A selection of new telecommunication services for businesses:
Tele marketing
World Wide Web advertising
E-mail
Customer service help line
Global corporate networks
Intranet
Remote on-line archives
Video conferencing
Extranet
Intelligent network services
Data network services
Mobile data, wireless LANs
Electronic commerce, on-line shopping
Electronic Payments
Tele education

Box 27 *New services in telecommunications*

- Transport-services include a range of services in public networks, such as telephony-, telex- and data-networks;
- Network-services include protocol conversion and security services. These services enable customers to use specific services;
- Value-added services include network management, information and communication services, but also complex services like financial transactions, and applications for a selected group of users.

In this chapter we will argue that the wave of changes in telecommunications was initially sparked by technological innovations. Yet, the fuel that boosted the process of change, was supplied by technological innovation as well as by regulatory change. The technological innovations of the nineteen seventies and eighties offered a wide extension in telecommunication capacity, reliability, products and services. Especially the switch-over from the analogue, electromechanical paradigm towards the digital/optical paradigm has boosted the process. However, the full benefits of such innovations could only be enjoyed under open market conditions. Therefore, technological innovations were accompanied by, and closely entangled with regulatory change. The previously untouchable position of the telecommunications monopoly was gradually dissolved and the markets for telecommunication products and services were opened, which allowed new entrants to offer equipment and services at competing prices.

This process of technological change as well as regulatory change started in the USA. The United Kingdom and Japan were the first to follow and these countries liberalised their telecommunications market. The Netherlands was the first country on the European continent to liberalise its markets and privatise the former PTT.

In section 6.2 we will discuss the point of departure. We will start with a brief evaluation of the classical setup in telecommunication services and industry. We, then, in section 6.3, will discuss international developments, especially in the USA, which have put pressure on the process towards change. Section 6.4 will discuss how the Dutch operator and industry have reacted to the changes in the international environment, most notably, how the process towards modernisation of switching equipment has taken place. Especially, Philips' role as the main supplier of the Dutch operator will be discussed in greater detail. In section 6.5 we will discuss the process of regulatory reform in the Netherlands, while section 6.6 will discuss the results of technological innovation and regulatory reform. In section 6.7 we will discuss the implications for telecommunication research. We will argue that the setup of research activities initially tended to strengthen the science-driven approach with its classical, linear setup of research activities. However, under the influence of opening markets, several niches were most successfully exploited.

6.2 Point of departure: the classical setup of the telecom monopoly

6.2.1 Telecommunication organised as a natural and legal monopoly

As in most other European countries[1] the Dutch telecommunications operator was organised as a national monopoly. The rationale behind this organisation structure is obvious; the large capital investments needed to set up a telecommunication infrastructure, which could offer full coverage under uniform prices, are particularly unattractive for private actors. Given these high costs the monopoly appears as a natural monopoly. But governments have also actively excluded other parties from exploitation, by granting the sole concessions to the natural monopolies, which also gave them the legal monopoly. That has not just been the case for telecommunication, but also for other large infrastructures like the railroads or the provision of water, gas and electricity. All these large infra-structural works used to be organised as state-owned monopolies. The big advantage of monopolies is that they have the scale to offer uniform services at relatively low prices. However, the disadvantage of a monopoly is that a stimulus to offer services at competing prices is virtually absent. Furthermore, a stimulus in large monopolies towards innovation is usually low.

6.2.2 The roots of the postal-industrial complex

The Dutch government was relatively late in interfering in the telecommunication sector compared to other European countries. Initially it had failed to recognised that, if the organisation of telecommunication services was just left to private parties, it would probably remain the privilege of the citizens in densely populated areas. For private companies it was particularly unattractive to exploit telecommunication services in rural areas, because the costs of the infrastructure were much higher than in densely populated areas. Furthermore, it had failed to recognise that telecommunication had such a high potential to generate revenues for the Treasury.

The State changed its initial policy under the influence of three conditions. First, the need for technological and regulatory coordination increased with each extension of the telecommunication network. This was especially the case in long distance and international transmission. Second, it was clear that the quality of services in several areas remained below par, while government lacked the instruments to interfere in what was increasingly seen as the provision of a public good. Third, the potential of telecommunication to generate revenues for the Treasury was increasingly recognised. The State Post and Telegraph service (later PTT) was granted the concession to provide general telecommunication services under uniform tariff-conditions. This implied that each household in the Netherlands could enjoy telecommunication services no matter its location. Households in scarcely populated rural areas enjoyed telecommunication services under the same conditions as households in urbanised areas. Prices and tariffs were thus detached from the actual costs and set by the Ministry.

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[1] The Finnish local telecommunication services for instance were organised in regional monopolies; long distance services were organised by the national telecommunication operator.

The PTT monopoly was accepted throughout the post-war years, even though the tariffs and prices were clearly above cost price. Even the fact that Government used PTT revenues to balance its general budget was accepted, albeit grumbling. The reason is that the telecommunication system was beneficial for several parties. Government benefited because it could generate revenues. The telecommunication industry benefited, because it could rely on long-term contracts and generate high profits, the unions were contented because the telecommunication operator as well as the telecom industry, were very important sources of employment. Even private residents have benefited. Tariffs for private subscribers were relatively low, because business and industry compensated the telecommunication system with relative high tariffs. Finally, PTT benefited, because it could generate funds to reinvest in the extension of the network. However, the fact that the inefficiencies of the system were largely hidden by a general downward trend in tariffs, restrained citizens to object.

6.2.3 Stable relations between operator and industry

Even though PTT was one of the largest employers in the country, telecommunication was hardly seen as an independent economical activity, with dynamism of its own. It was rather seen as a public utility, subservient to the economy as a whole. The relations that PTT had with its equipment-suppliers beared the hallmark of the monopolised telecommunication structure. Relations were tight and very stable over time, with practically fixed market-shares for each supplier. There was practically no need for industries to invest in marketing and sales activities. Instead, the companies could lean back and wait for their annual phone-call to jot down the next PTT order (Roobeek, 1988, p. 324).

As in most other European countries, this system was highly protected. The national telecommunications-industry had a privileged position and foreign suppliers were only acceptable if the production-works were based in the country. In the classical analogue system of the early nineteen seventies we find the Philips Telecommunication Industry (PTI) as the main supplier with a market share of approximately 70%. The remaining 30% was equally divided among Swedish Ericsson and US based NSEM, which later merged into Alcatel. These latter firms had large production facilities in the Netherlands. Supplier industries, such as the transmission and cable industries were also closely interwoven in this system. The biggest cable-supplier NKF actually belonged to the Philips Holding for several years, but apart of that, these companies were mutually involved in cartel-like structures, which provided them with an extremely stable position.

In fact, the telecommunication industry was so closely interwoven with the national operator, that it belonged to the same monopolised structure. Variety was only caused by fluctuations in PTT's annual budget and by exports. Exports were considerable in transmission equipment (esp. broadcasting-transmitters and radio equipment), but very low in switching equipment, because the European countries had all sheltered their markets against new entrants.

It goes without saying that telecommunication research then, involved only few actors, who were mutually linked in that same monopoly-like structure. Their main field of orientation was how to extend the performance of the telecommunication network, thus mainly oriented towards transmission technology. The basic division of labour between the operator and the industry was transparent: the operator mainly concentrated on network management and system development, while the industry had a much stronger focus on technological innovation in equipment. However, the involvement of both industry and operator in each other research portfolio was such that the two main actors in research often joined forces. Competition in telecommunication research was virtually absent

6.2.4 Change of demand

The stability of the telecommunication structure could have lasted for years if not several important developments had happened. The first signs that could be observed in the Netherlands were in a change of demand. In the early nineteen seventies it was obvious that business as well as private subscribers had increasingly trouble to accept the paternalistic attitude of the PTT, which compelled subscribers to the sole use of PTT telephone equipment. Innovation at PTT was lacking and many subscribers purchased telephone equipment from abroad (the Danish telephone-sets were fully compatible), or in newly emerging telephone-shops. These shops could exist in the dusky zone of regulations because it was not forbidden to sell telephone sets. It was, however, forbidden to connect these telephones to the public net. Yet, these telephone shops were able to sell fancy equipment at a competitive price, which challenged PTT. When it was clear that PTT could not turn the tide, PTT opened its own telephone shops and relaxed its regulations regarding end-user equipment.

Second, demand for services changed. Historically demand was based on public (voice) telecommunication, but, with the increasing use of computers in the office-environment, the demand for data-transmission services sharply increased. Therefore, in 1982, PTT opened its packet switched DN-1 net, especially for data transmission. The attractiveness for the business and science community to rent capacity on this data network was not only its speed and capacity, but also that it was connected to several data networks abroad. In 1985 it had already 1,400 subscribers, but within three years this number had been multiplied by five. The amount of data in that same period had multiplied by six, which indicates that not only the number of subscribers increased, but especially the amount of data per subscriber (Hogesteeger, 1989, p. 211).

Third, the business world put pressure on PTT to modernise and extend the capacity of the network and to calculate fair market prices for the services. This particular demand did not come out of the blue; it was strongly induced by the growing internationalisation and the globalization of world-markets, which was especially important for a trade-oriented country as the Netherlands..

It was obvious to see that the regulatory system, that had served so well until the nineteen seventies, increasingly had produced counterproductive elements. The monopoly like structure of the telecommunications service and telecommunication industry lacked the flexibility to adjust to changing market conditions. It also lacked the innovative capacity to take the lead in technological innovation, both in the provision of equipment as well as in the development of new services. This was not an exclusive development for the Netherlands, but its gravity was particularly felt, because the Dutch economy has a strong international orientation. Changes abroad could easily afflict Dutch competitiveness in international markets.

6.3 International developments as a forerunner for change

6.3.1 Technological change in the USA

The shift towards the change of the technological paradigm, as well as regulatory reform was induced by developments abroad, especially in the USA, which started already in the nineteen sixties. The launch of the first US telecommunication satellite ‘Telstar I’ marks the beginning of a new era in telecommunication. This satellite offered an alternative technology for long distance transmission. This opened the door towards competition, because the Telstar satellite could transmit the same message at a much lower price than the until then available technologies.

Telstar’s launch has been model for parallel developments in transmission and switching. Experience in the USA had clearly demonstrated that the new, computer-aided switchboards (SPC switchboards) had outperformed the classical electromechanical switches. The high costs of development were easily recovered because the performance allowed for more speed and much higher capacities. Increasing revenues thus compensated for the initial costs of development. On top of that, these modern switch boards were low on maintenance-costs, because a range of managerial functions could be performed by a single operator from a central terminal, rather than by a sizable workforce at each switching node. The transition from the classical, electromechanical to the modern electronic components allowed for new, more powerful, and eventually less expensive customer premisses and network equipment.

The logical next stage of development in telecommunications, was the design of a full electronic switch. Leading telecommunication researchers of the two most prestigious laboratories in the USA had envisaged that the binary structure of computer signals would provide the best platform for future telecommunication systems. This has set the research agenda in the USA towards digitalisation. As soon as the first electronic components came available, it was clear that equipment could be produced at a much lower price than ever before.

6.3.2 Regulatory change in the USA

The technological process towards digitalisation has coincided with the process of regulatory change. By 1975, competition in the US had advance to general long distance services, and as a consequence of US deregulation policies in the nineteen seventies, the market was gradually opened to foreign competitors. Imports from Japan and the Far East had decreased the market share of domestic competitors and had worsened the US trade-balance. American anxiety over this increasing importance of the steadily growing market shares of Japanese firms in the American domestic market for information technology and micro-electronics, together with the protectionists' nature of the Japanese market, were underlying factors of a high risk strategy to free IBM and AT&T from their anti-trust constraints (Tunstall, 1986). The anti-trust suit began in 1974 and was finally settled in January 1982, when AT&T agreed to divest itself into seven regional Bell operating companies. In return, the US Department of Justice agreed to lift the constraints of the 1956 decree[2]. This basically allowed AT&T and IBM to expand its business to other regions (cf. Hochheiser, 2001).

The bigger goal of deregulation was that it would make the US industry more competitive in the home market, but also strengthen its position on the world market. It was believed that international competition in an open market-place was the best way to combat European and Japanese protectionism. Although deregulation in US telecommunications gave foreign companies the right to invest in the American economy, the position of the US in the various segments of the telecommunication market at that time was so dominant that foreign investments did not pose a real threat (Hulsink, 1996, p. 114).

The US initiative to liberalise its telecommunication market was soon followed by the United Kingdom and Japan. Both countries liberalised their markets already in the mid-nineteen eighties and deregulation was high on the agenda of the continental governments and telecom monopolies.

6.3.3 Changing perspectives in standardisation

The change of the regulatory structure has also changed the institutional setup in telecommunications. Until then, international standardisation was the domain of national administrations and the International Telecommunication Union (ITU). However, in 1986 an agreement was reached to make the provision of international telecommunication services subject to the GATT's jurisdiction. The role of the ITU was furthermore challenged by newly erected regional standardisation bodies as the European Telecommunication Standards Institute (ETSI), T1 in the USA, and TTC in Japan, and the increased importance of the International Standards Organisation (ISO) at the world level (Rutkowski, 1991; Besen and Farrell, 1991; Hulsink, 1996).

The change of the international scenery has radically changed the perspectives for the European telecommunication industries and operators. All that had seemed so stable for so long, started to stagger and the European governments, telecommunication operators and telecommunication companies had to rethink the future. The scope had broadened and, no doubt, the US was the technological leader, on average ten years ahead of European developments (Metze, 1991, p. 140).

6.4 Modernisation of switching equipment in the Netherlands

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[2] AT&T has functioned as a legally sanctioned, regulated monopoly. In 1907 its president Theodore Vail formulated this principle, that the telephone by the nature of its technology would operate most efficiently as a monopoly providing universal service Vail wrote that the provision of monopoly rights was an appropriate and acceptable substitute for the competitive marketplace. The USA government accepted this principle and one notable result was an antitrust suit filed in 1949, which led in 1956 to a consent degree, whereby AT&T agreed to restrict its activities to the regulated business of the national telephone system and governmental work..

6.4.1 Philips dominant position in telecommunication

In previous chapters we discussed that the market-structure for telecommunication equipment has developed along the lines of the former private-owned companies, each having its own supplier. Shortly before World War II it was decided that Siemens would be the future supplier for Dutch PTT, but after the war Siemens was no longer welcome. Its establishments and patent-portfolio were regarded spoils of war and were used by Philips to further extend its telecommunication branch towards public switching technology. Philips gained considerable market-shares, but PTT chose to purchase equipment from Ericsson and NSEM as well. However, Philips played the leading part in the modernisation process of the nineteen seventies and eighties. The reason is that both research and production were based in the Netherlands, while NSEM and Ericsson equipment was provided off the shelf. The research laboratories of the latter two companies in the Netherlands were only meant to adjust equipment to local conditions. The ties between these laboratories and Dutch PTT were very loose, while the ties with Philips were comparatively strong. That is the reason why the story of modernisation of the Dutch telecommunication network is basically the Philips story.

6.4.3 The introduction of digital technology in the network

By the end of the nineteen seventies it was clear that the future in telecommunication was in digital equipment. However, Philips lacked the technological skills to build an independent digital switching system. To survive in the telecommunication industry it was necessary to find a strong partner, preferably one which had already won its spurs in digitalisation. There were two possible candidates: Northern Telecom and AT&T. Top-management of Philips' telecommunication branch (PTI) had an outspoken preference for Northern Telecom (Canada). This company was not only the first to develop a full-digital switch, but it was also the first company that had successfully managed to penetrate the well-protected US market. This company had built up experience in foreign markets and could provide a bridge-head into the US market. Conversely, Philips was an attractive partner to Northern Telecom, because it hoped to use Philips as a bridge-head to the European market. However, Philips' board of directors decided differently. Gerrit Jeelof, by then the new 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 also fierce resistance in the board of directors, who feared AT&T's lack of international experience, Jeelof and president 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 of its CEO Lorentz- its German subsidiary PKI. An interesting detail however, is that Lorentz some years later managed to free German PKI from the APT deal (for further reading: Metze, 1992, 1997).

APT managed to get access to the Dutch market (75% market share) and the Saudi Arabian market (50%). Dutch PTT had committed itself to 5ESS equipment and was among the first European operators that decided to fully digitalise its network. APT's turnover rose by 50% in the first three years, but even then did not break-even. It heavily leaned on sales in transmission technology, in fact, the traditional Philips part. The joint venture with AT&T in APT did not bring the success that Philips had hoped for. What was designed as a triumph of synergies, turned out to be a loss-making game.

First, the 5ESS switchboard, which was supposed to be APT's flagship, needed much more adjustment to fit the European standards than was foreseen. Second, it turned out to be much more difficult to enter the still well protected telecommunication market of other European countries. Furthermore, the persistence of national sentiments, especially anti-Americanism was largely underestimated. Where Philips had always managed to be a chameleon, taking up the colours of its environment and presenting itself as a national company, APT was obvious an US/Dutch company, and thus a threat to the domestic telecommunication industries. This was especially the case in France. APT had gone a long way to enter the French telecommunication market. It had submitted all the specifications, clarified all the technical details, and unfolded the secrets of the software. However, in sight of an agreement the order went to the domestic French telecommunication industry, which was licenced to use Ericsson technology. This remarkable step was discussed in the press as a revenge on Philips, because Philips had 'betrayed the European interests by its merger with an American company' (Dekker, van Lonkhuijzen, 1996, p. 224). 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 infrastructures. Furthermore, they were used to work in an open climate. The power distance between workers and management was traditionally small and workers had a large amount of discretion to take their own decisions. This was not specific for Philips telecommunication branch, but rather a characteristic of Dutch working relations which are generally governed by a tendency towards corporatism (van Iterson, 1977, Trompenaars, 1993; Andeweg and Irwin, 2002). Indeed there was an open work atmosphere between PTI researchers and their colleague- researchers from PTT. Researchers of both companies knew each other, many of them shared the same technological background and most of them had studied at the same university. In this climate, with its broad informal network where researchers knew each other often by first names, cooperation was easy-going, mainly building on trust-relations. This was totally different from the American work-attitude. Power distance between workers and managers was very large, and decision making was a case for the US headquarters. An interviewee put it like this:

> 'I remember well when the AT&T people came here first. It was a group of technicians and experts, all having a brand-new passport, because none of them had ever been abroad before. The group was accompanied by some social counsellors, because the Netherlands, well, that was 'underdeveloped territory. Those people came here with an attitude as if the Dutch engineers were just a bunch of simple technicians!
>
> That has caused a lot of tension, especially because most of the 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 Jersey headquarters was absolutely necessary, even for the smallest detail! We were rather used to the opposite. PTI researchers used to have considerable discretion and the organisation structure used to be -more or less- organic.'

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 it 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 shaken the fundament of the Dutch telecommunication research structure. Especially the balance between the main players (Philips and PTT) was heavily disturbed and was not replaced immediately by a new form of consensus between supplier and operator. Until then, the research organisation of both companies had fit together like the pieces of a jig-saw puzzle, but APT centralised approach has put this system under severe pressure. Decision making in the joint venture was strongly centralised in AT&T headquarters and cooperation between the Dutch operator and its main supplier was greatly disturbed.

Philips' withdrawal from public switching has marked the end of independent telecommunication research in the Netherlands. AT&T continued research activities, but rather as a downsized replica of its US Bell Laboratories than as a telecom laboratory with an independent research agenda. How can we understand this development? Did Philips lack the technological skills to develop a fully digitalised switching system? Was it lack of commercial skills? Or was it rather that the Netherlands have suffered from the small-country squeeze? Van Tulder (1988, 1991) has introduced the term to point out the process that smaller countries are stuck between the pressures from the larger industrialised economies (who are involved in the active promotion of high technologies), and the newly industrialising countries, who try to capture the lower ends of the market. Major economic developments have taken place beyond the reach of the smaller countries. They lack sufficient resources and economies of scale to participate in the global technology race. As a result the freedom of action for the smaller developed countries is restricted to the diffusion and application of new technologies and to specific market-niches (Hulsink, 1996, p.203).

We will argue that it has been a bit of both; lack of technological and commercial skills as well as van Tulder's concept of the small-country squeeze.

6.4.3 Philips' failure in digital switching technology

Philips' engineers[3] must have been aware that engineers at the most prestigious North American telecom research laboratories had set the research-agenda of the nineteen seventies towards digitalisation. Philips researchers were among the first to have knowledge about new developments in materials, electronics, optics and other new products that were developed in US laboratories. They also had the opportunity to see which technologies resulted in commercial attractive products. Philips' strategy had long relied on picking winning technologies from the USA, improve them and sell them to gain the lion share of the European market (Metze, 1993, pp. 140-142). It had done so in radio, television and many other consumer electronics and it had been extremely successful using this strategy.

One might thus have expected Philips to follow suit in digital technology, but it did not. It must have thought that digitalisation was still a step too far for the sheltered European markets. Moreover, by the time that the North American laboratories set the agenda for digitalisation, Swedish Ericsson challenged Philips in its home market with the introduction of SPC equipment. This renown company with its established position in the European telecommunication market had clearly outperformed Philips by installing its first SPC switchboard in Rotterdam in 1971. Thus, in the early nineteen seventies Philips was under the threat that Ericsson could undermine its dominant position in the Dutch telecommunication market. Philips has tried to develop a full-electronic switch, but it was not able to master the technology. The electric resistance of the electronic components muffled the signal too much, which was another reason for Philips to opt for the analogue SPC switching units. The design of these switches were rather similar to the Ericsson switchboards (van Hilten, 1981, pp. 77-78).

The technological setup of the new SPC switch may have looked outdated at the time of introduction, but there were additional reasons, next to the challenge posed by Ericsson.
The technology to produce reed-relays was a rather familiar technology for Philips' engineers. Philips had built up considerable expertise in glass-technology, especially in light-bulbs, vacuum tubes and radiation tubes. The reed-relay was more or less a variation on the theme. Second, Philips was involved in the production of transistors, but knew that this technology at that time 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. Third, digital technology did not find fertile ground in the mind of Philips engineers and management. Telecommunication researchers who tried to engage in digital technology were actively discouraged, because Philips' main products were all based on analogue technology. Leading scientists and researchers did not expect that digital technology would soon find solid ground, not in telecommunication, nor in consumer electronics.

Yet, next to these reasons which all had a direct impact on the development of telecommunication equipment, there were some other reasons which were rather linked to Philips' general business strategy. Philips simply had difficulty in grasping that international competition had fundamentally changed. It still believed that the world's leading companies could rule in a regulated market, and mutually could agree upon world-market-shares in several technologies. For instance, Philips had a deal with IBM, the then leading producer of computers. The deal entailed that Philips would be IBM's sole supplier of computer components, under the condition that Philips would not step into computer-technology and production.

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[3] Philips Telecommunication Industry (PTI), which was a full subsidiary of Philips had its own research department, which was basically involved in applied research. Basic research, but also strategic decisions were taken by Philips' board of directors. In this section we use 'Philips' as the main actor, to point out that much of the strategic dimensions were beyond the reach of PTI's management.

Philips initially kept its side of the deal, but when IBM purchased components from other suppliers, Philips still decided to step into computer-technology, although much later than much of its competitors. Even this did not ring the alarm-bell that relations among leading technological firms had already changed.

Philips' perceptions of future market developments were basically built on the solid experience it had gained from the past, wherein large companies could easily set up cartels, or divide world-markets among a few big players. Philips has been part of many cartels. Notorious for instance was the Phoebus cartel[4] in lightning, which covered the whole world except Canada and the US, which countries were regarded to be the 'domain' of the US cartel, with General Electric as the leading company. Philips was also involved in cartels in the radio-industry and it has always believed in and fought for rationalised and regulated trade through private international agreements, because this was thought to lead to stable markets, stable employment and a rapid exchange of technological innovation. The company, which was a true advocate of this policy, would only give up this principle if it was forced to (Fortune, 1945). Although Fortune already made its remarks in 1945, and even though the political climate had changed since World War II, Philips persisted in several cartel-like agreements. There was for instance, the 'gentlemen's agreement with General Electric not to penetrate each others markets in lightning activities. In the nineteen sixties and seventies there were several market agreements with Matsushita and Sony in the case of the video-recorders, and still in the nineteen eighties in the case of the CD-player. Furthermore, the European telecommunication market tended to strengthen this belief, because it was a true example of a regulated market.

Philips' strong beliefs in the benefits of regulated markets strongly resembled the characteristics of the large monopolies. Indeed it dominated the market and could produce in a cost efficient way, but it trailed behind developments. It had built up a serious backlog in computer-technology and in telecommunication technology. Thus, building the computer-power which was necessary for a full-digital switchboard was a step too far. '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 modern digital systems; 60 to 80% of development costs were on software. (Roobeek, 1988, p.298)

1980	1985	1990
Alcatel Thomson ITT Telettra	Alcatel ITT Telettra	Alcatel
AT&T APT GTE Amper	AT&T GTE Amper	AT&T
Siemens Rolm Nixdorf GEC Plessey Stromberg-C GTE	Siemens Rolm (IBM) Nixdorf GEC Plessey GTE	Siemens

Table 33 *Example of concentration in telecommunication industries*
Source: Roobeek and Boeders, 1993

6.4.4 The concept of the small country squeeze

Next to the reasons discussed in the above, there has been a shake out in the telecommunication industry during the nineteen eighties. The joint venture between Philips and AT&T serves as a perfect example for this process, and it was by no means an exceptional case. Several smaller European telecommunication enterprises like Jeumon-Schneider, Telenorma, ANT, STC, Thorn, MET Matra) GTE, Plessey have met the same fate. A wave of mergers and takeover washed over the telecommunication industry in the nineteen eighties. By 1980 there were

[4] The 'Société Anonyme Phoebus pour le perfectionnement de l'éclairage' was established in 1924 and was one of the most successful cartels. It aimed at standardisation and price-control.

still twenty-seven telecommunication industries, but by 1990 this number had decreased to ten.

The main obstacles for the smaller companies were the large investments needed to develop digital systems. Furthermore, the market-structure in the nineteen eighties was still well protected which made it extremely difficult for companies to penetrate new markets. Ericsson had the advantage of being the second-supplier in several European countries, which provided the scale to earn back the costs of development. Ericssons's president explained that a telecommunication company needed at least between 1.4 to 2 billion dollars sales annually to recover the sky-rocketing research investments of new digital exchanges. Some companies could find shelter in the protection of the home-market like Siemens in Germany or Alcatel in France, but it was evident that a shake-out in the telecommunication industry was at hand and only few companies could survive the digital battle of the nineteen eighties. In his view there were only few candidates to develop into the strong players: AT&T and Nortel in the North American market, two Japanese companies and three European companies, notably Alcatel, Siemens and Ericsson.(NRC-Handelsblad, 1987)

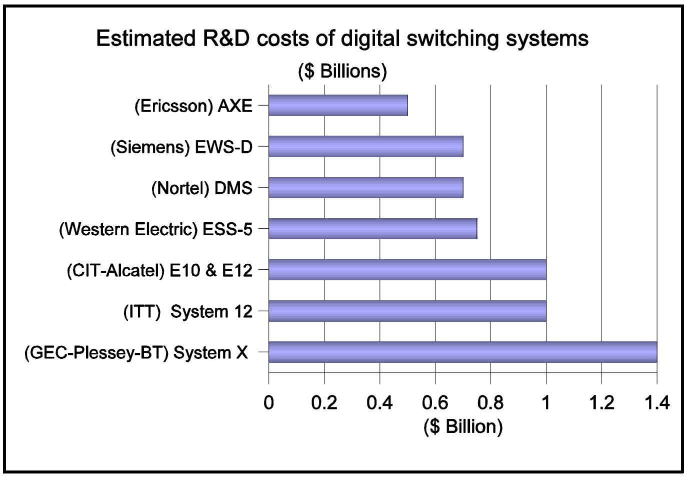

Figure 47 *Estimated costs of R&D for digital switching systems*
Source: Roobeek, 1988

What has frightened European companies was that the life-span of a system was expected to decrease. Twenty-five years for a classical electromechanical system, twelve to fifteen years for an SPC system and only eight to twelve years for a fully digital system (Van der Klugt, 1987). This was even an optimistic scenario; others have estimated a life-span of only eight to twelve years for SPC based technology and only five to eight years for digital systems (Dinklo, 1988; Roobeek and Broeders, 1993). However, this has proven to be a mis-calculation; the digital systems that are introduced in the nineteen eighties are still fully operational. They have been updated time and time again to meet the increasing requirements of modern telecommunications. It is, however, obvious that the flexibility of digital equipment was not recognised at the time of introduction. Digital technology was seen as a new generation of switching technology, which would soon be outdated by another generation, probably based on another technological paradigm.

None of the smaller European telecommunication industries has survived the battle of giants in the field of public switching. The concentration process in the telecommunication industry clearly reflects van Tulders concept of the small-country squeeze. Indeed, the Dutch telecommunication market was too small to earn back the costs of development and there were no prospects of entering new markets. But Philips' withdrawal is not solely the result of this process. Philips has also failed to recognise the changes in the international telecommunication market and has sticked too long to superseded views.

6.5 Regulatory reform in Dutch telecommunications

The discussion on deregulation, liberalisation and privatisation may have been fuelled by international developments, but the debate had several genuine Dutch accents, which have coincided with the international tendency towards the increasing liberalisation of the telecommunication market and privatisation of the national operator. There were basically two elements. One was the long standing discussion in the Netherlands about the legal status of PTT as a state-owned company. PTT has felt the pressure and constrains of Government and parliament, and it felt that it could not develop its potentials as it should from a business point of view. Throughout the postwar years it has fought a battle for greater independence. Second, there was the discussion in the early nineteen eighties on how to cure the ''Dutch disease'. The characteristics of the disease were that the Netherlands had developed an extensive welfare system in a just a few decades. However, the financial burdens of its programmes could not be covered from tax and premium income. Therefor it was decided that the incomes from the sale of natural resources (natural gas) would be allocated to welfare programmes instead of improving the economic infrastructure. This was an extremely risky decision, because the income-source would eventually dry up.

In the section below we will discuss how these two developments have coincided with the international trend towards liberalisation and privatisation of the telecommunication market.

6.5.1 PTT''s legal status: setting the agenda for privatisation

Historically, the setup of Dutch telecommunication structure 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 Post and Telegraph designation act established PT[5] as a departmental office of the Ministry of Transport. PT had an annual budget, but the size of that budget was not directly related to PT's own revenues. 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 for PTT. It lacked the independence to act and develop like a real business. It often felt as if Parliament was taking the driver's seat. The lack of freedom for PTT management became painfully clear between 1959 and 1965, when government curtailed investments, as part of a general reduction of public expenditure. As a consequence, the waiting list for new subscribers increased dramatically (Ottenheijm, 1974). Furthermore, it was not allowed to negociate loans on the capital market, and thus PTT was severely curtailed in making long-term investment plans. On top of that, PTT had serious problems with the recruitment of (qualified) personnel, a brain-drain of staff to the private sector, and the formal restrictions posed by the uniform standards for civil servants. As a consequence, PTT could not compete with private enterprises (Hulsink, 1996, p. 224).

The Ministry considered PTT as 'the goose with the golden eggs'. For this parochial point of view it was heavily criticised by organised business: "In a period when restraint is more than ever required, it has to be considered as unacceptable that customers of the PTT-services have to contribute indirectly through higher rates to the government's budget deficit. It makes it all the more obvious that in the short term a change in the state-owned PTT is desirable, by reducing the company's dependence on the government's budget." (NRC-Handelsblad, 1973; also Slaa, 1987; Hulsink, 1996).

PTT's monopoly was criticised. and government as well as organised business were convinced that a thorough reconsideration of the established regime and the effects of technological, economic and international developments in telecom was required (Hulsink, 1996). The Minister held out the prospect of a gradual move towards more market conformity and more autonomy for PTT concerning tariffs and investment decision, on the condition that permanent positive results would be achieved (Slaa, 1987). Several committees have studied this subject, but none of them managed to bring real changes.

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[5] Only Post and Telegraphy were represented in the name. Telephony was added only in 1928 when PT changed its name into PTT.

6.5.2 Curing the 'Dutch Disease': liberalisation as strong medicine

The economic recession of the nineteen eighties brought a general change of policy. Government expenditures throughout the nineteen seventies had far exceeded its income. The incomes from natural resources were used to finance its high-priced welfare programme, even though it was a source of income that eventually would dry up. Furthermore, it had become an accepted practice to increase the size of the budget deficit. This process, which is generally known as the Dutch disease, had reached intolerable levels of the financing deficit in the early nineteen eighties. Finding a cure was not easy and strong medicine was needed. Hoogenboom and Van Vliet (2000) have argued that the recovery rested on five pills, some quite bitter: (1) reduction of wage costs, (2) reform of the system of social welfare, (3) restructuring of government finances, (4) improvements in the functioning of markets, and (5) provision of a stable monetary climate.

During the nineteen eighties the first steps were taken in a process of liberalisation and privatisation of utilities and semi-public facilities, such as electricity, gas, public transportation, postal services, telecommunications and social programmes. Many public utilities were privatized and regulations were liberalised. Privatisation did little to reduce the size of the collective sector, but increased competition did lead to reduction in prices. Monopolies were attacked and Dutch companies were required to adhere to EU standards in the awarding of contracts (Andeweg and Irwin, 2002, pp. 186-91).

The Lubbers I Cabinet[6] envisioned a drastic 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 it was expressed in Parliament.

From that moment on three discussions got intermingled. The international tendency towards liberalisation of the telecommunication market coincided with PTT's desire for greater independence and Government's general economic strategy.

From 1984 onwards the Cabinet has developed an active policy towards deregulation, liberalisation and privatisation. The first ideas, regarding competition in telecommunication-market were foreseen for certain advanced services and advanced terminal products. A dissolution of PTT's monopoly was foreseen on the procurement of advanced or non-traditional terminal equipment, thus giving room to improve technological innovations. However, PTT was thought to hold its monopoly in the supply of traditional equipment like telephones, private branch exchanges, and telex equipment. This mainly for reasons of protection of the domestic telecommunications industries.

It was especially the Steenbergen Committee that drew the outlines for a future telecommunication structure. The committee separated PTT's traditional activities into four functions:

- the public utility function, which entailed a responsibility for the construction and maintenance of the infrastructure and basic services;
- an entrepreneurial role regarding the provision of value-added network services and equipment in an open market environment;
- a regulatory task, regarding standardisation, rule setting and supervision;
- a policy supportive function, regarding advice and recommendations on government telecom policy.

In 1985 the cabinet endorsed the broad outlines of the Steenbergen report, which was a perfect match with government's general policy on privatisation and deregulation. Innovation and competition in the provision of telecommunication facilities were encouraged, 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, one for

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[6] Ruud Lubbers has been Prime Minister in three successive Cabinets: Lubbers I (1982 - 1986), Lubbers II (1986 - 1989), Lubbers III (1989 - 1994)

telecommunications and one for post, both subject to civil law. This future PTT, with the state as its sole shareholder, should also have the 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, p. 236). 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 recommendations were followed. There was, however, debate about the proposal to split PTT telecom into a public utility company for infrastructure management and a commercial enterprise for services. In the best of Dutch traditions, parties found a compromise in 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.

6.5.3 Supervisory reform

The liberalisation of the market and privatisation of PTT into KPN also changed 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 and had to integrate several policies. At the European level it was responsible for the general policy on telecommunication and competition, at the national level for technology- and competition policy for the Ministry of Economic Affairs, and 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 KPN's 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.

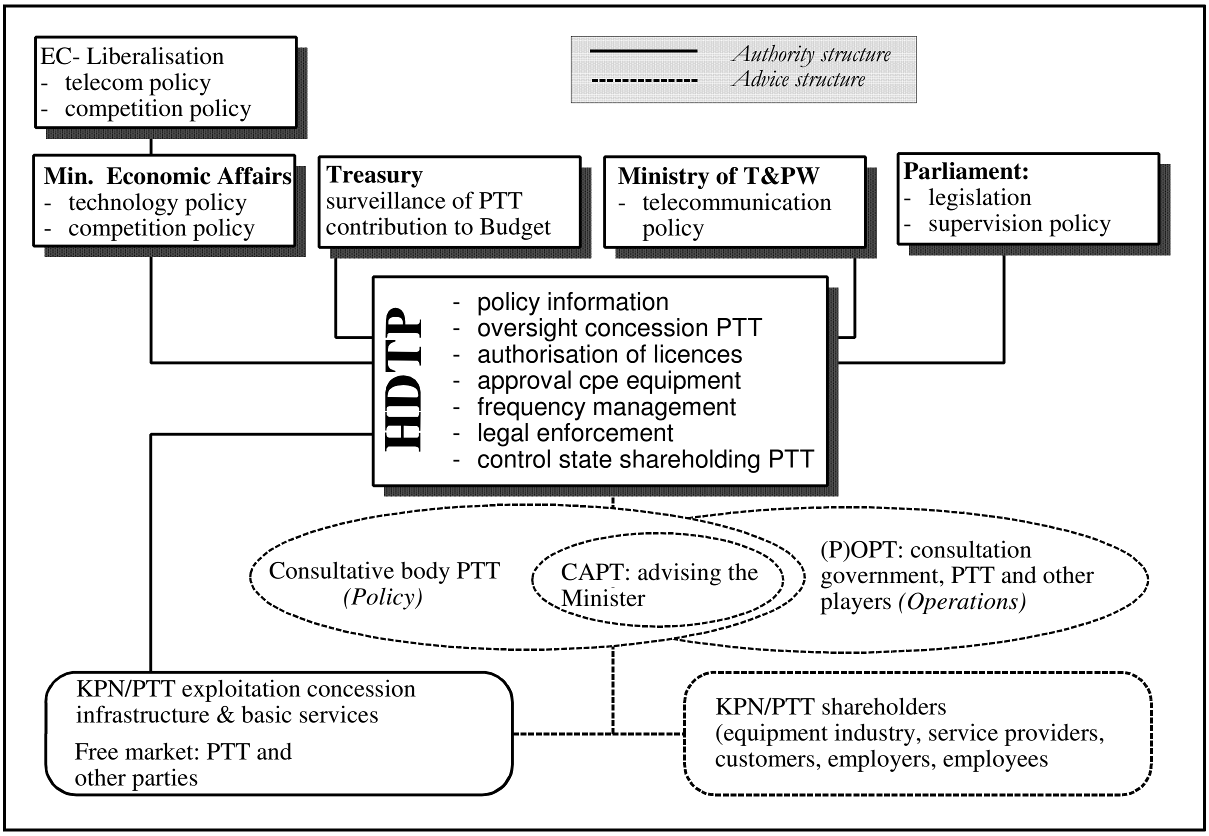

Figure 48 *Regulatory and Advice structure in Dutch telecommunications 1992*

The Consultative Body Postal and Telecommunications (CAPT) 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 into the Commission for Advise on Postal and Telecommunication Policy (CAPT), 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.

This new design for a regulatory and advice structure had shortcomings from its beginnings. What was meant to be a balanced exchange of information between actors, did not only have 'teething-problems'; HDTP was not an equal player for 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, p. 273).

The design of the regulatory structure had largely overlooked the increasing jurisdiction of the European Commission in the field of telecommunication and the Dutch 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, numbers-planning, etc. The Dutch governance regime, which was characterised by retreat of state interference, had trouble in coping with the detailed system of regulations that was 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 new body 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. With the regulatory reform the basic structure for a liberalised telecommunication market was completed.

Deregulation and liberalisation of the US, UK and Japanese telecommunication markets have most certainly affected the discussion about the post en telecommunication structure in the Netherlands, but it was not the only pressure. It is rather that the ideas fell in fertile ground. PTT had privatisation high on its priority list and the economic situation of the nineteen eighties allowed for such drastic changes. The Netherlands was the first on the European continent to liberalise its telecommunication market. However, the Dutch approach was not as drastic as the tree countries that had taken the initiative. It rather showed a balanced approach between the liberalisation of the market and an exclusive position for the privatised public operator on network-provision. Just because the Dutch response has been relatively moderate, it has served as an example for other European states (e.g. Germany, Belgium, Portugal) to restructure their domestic telecommunications industry (Hulsink, 1996, p. 203-4; Wieland, 1986; Foremann-Peck and Müller, 1988, Arnbak, 1989, Noam, 1992).

6.6 The results of technological innovation and regulatory reform.

Technological innovations have injured the stable, classical structures in telecommunications. The introduction of new technologies has offered more speed, more capacity and more services at lower prices. These new prospects made it attractive for new economical actors to enter the telecommunication sector and this has hollowed the ‘raison d’être’ of both the natural and the legal monopoly. Technological innovation initially just opened the possibilities for an open market approach, but innovations could only be developed to the full extent under new, liberalised market conditions. This was especially the case after the introduction of digital equipment, because the digital environment offered a flexible platform for new services to develop. The architecture of digital networks allowed for much greater flexibility than the old electromechanical systems. A range of new services was offered to public subscribers, but the true revolution took place in business systems. These were increasingly tailored to meet the special requirements of business and industry. The process-industry for instance used telecommunication systems for the management and control of industrial processes. Banks used the telecommunication system for financial transactions and setup the company Interpay to manage the use of debit, credit and chip-cards. Real estate brokers set up a telecommunication network to keep each other and the customers informed about new properties. These are just three examples, but the list can be extended, almost into infinity. In comparison to these highly specialised products and services, and despite the introduction of a range of new products and services in the public network, the public telecommunication network still is a model of simplicity.

This can be explained in two ways. First, business and industry were much better equipped to articulate their demands toward the telecommunication companies, than individual private subscribers were. Second, the market for business-equipment was one of the first to be liberalised. This provided the head start to develop specialised services, as the few we mentioned before. In many respects the business-community has been a laboratory for the development of new services in the private networks.

6.6.1 Gradual liberalisation of the telecommunication market

Indeed, the liberalisation of the market was also organised in a step-wise mode. It started in 1989 with the liberalisation of the market for end-user equipment (which included business systems), and - shortly after in that same year- the market for data-transmission. The market for mobile communication was opened in 1994. The final piece was the liberalisation of the fixed-line telephone-market in 1998.

As a result of (international) liberalisation of the telecom-market, several changes have occurred.

First, demand for new services and transmission capacity has sharply increased, especially regarding data services. Second, liberalisation has led to changed market-relations, sharply decreasing tariffs, and new forms of services. Third, the choice of technology has strongly been provoked by the success of the Internet. The Internet Protocol has gained importance next to the traditional, voice-telephony-based architectures. These three developments are mutually interwoven and strongly influence each other. Together they have radically changed the structure and economical characteristics of the market.

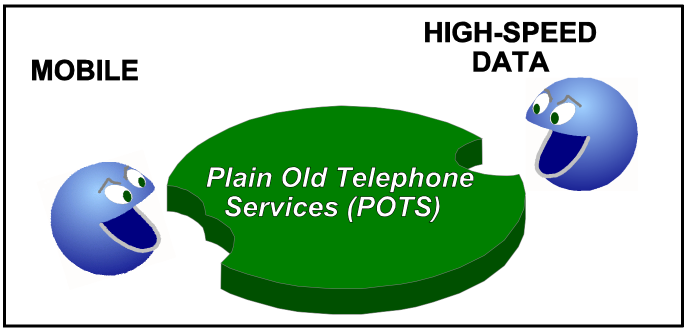

Figure 49 *Dislodgment of traditional voice-based services*
Source: DDV/Ministry of Economic Affairs, 1999

The main-streams of development have concentrated in an increasing dominance of data-transmission in fixed line communication, further pushing aside voice-communication, and in a tendency that voice communication is increasingly handled over mobile systems. Especially in the late nineteen nineties, telephony has changed from location-bound communication into person-bound communication, and the expectations are that this process will continue.

The dynamism of the liberalisation-process has however, followed a different trajectory than most policy-makers had foreseen. The Dutch government initially proposed to introduce network competition by allowing private[7] companies with way-leave, to sell excess network capacity to third parties. By offering a premium for a nation-wide licence to provide an alternative fixed-line network, the Minister intended to stimulate the cable operators, Dutch rail NS and the power utilities to integrate their already existing networks[8] and merge their business into a new public operator. Encouraged by government to become the single competitor of PTT-telecom, the local/regional power utilities (owning about half of the cable network) and Dutch rail NS decided to join forces and established the Enertel/NS Consortium with the power utilities having a 75% and the railways a 25% participation share.

[7] 'Private' is printed in italics, because these were basically state-owned companies, or companies exploited by regional or local authorities. Here we can think of the power utilities, the railroad company NS and CaTV companies.

[8] PTT used to hold the exclusive licence for public bi-directional telecommunication services. However, large companies like Philips, Shell and DSM and several other firms had already installed extensive telecommunication networks for internal use on their own premisses. For these networks no licence was needed. For the connection between two different locations, these companies leased capacity on the public network. Yet these networks had only limited capacity. The railroads, public utilities and cable operators however, had installed networks, which (by and large) offered full coverage. They could do so because they were licenced (the cable operators), used their own power network (power utilities) or the network was built on their own premises (railroad company).

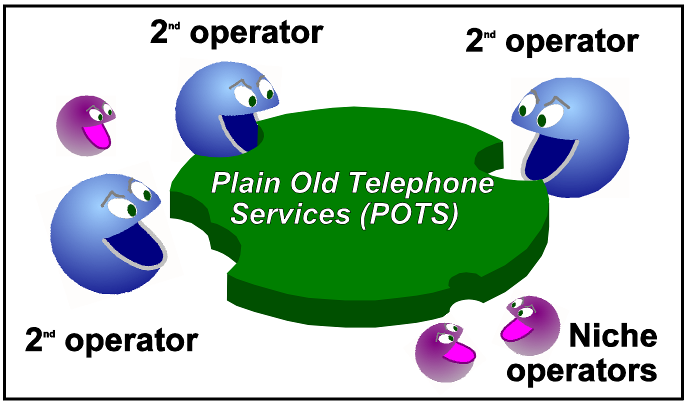

Figure 50 *The expected structure of the telecommunication market after liberalisation*
Source: DDV/Ministry of Economic Affairs, 1999

Instigated by the government's condition to grant the licence if a nation-wide coverage would be achieved, the power utilities of the consortium started to acquire local CaTV networks and upgrade their infrastructure in order to make bi-directional switching possible. However, before entering into genuine competition, Enertel/NS sought temporary preferential treatment on the basis of the infant industry argument. The company demanded a permission for the provision of voice telephony, access to PTT-telecom network on cost-related interconnect charges, and asymmetric regulation, which included a temporary exemption from universal service requirements. In early 1995 Enertel argued that it should be allowed to participate in consortia bidding to establish a new GSM network; that it should not be subject to universal service obligations; and that it should enjoy exclusivity as a second fixed infrastructure operator for a period of time. None of these demands were met by government and Enertel was disbanded in June 1995 (Hulsink, 1996, pp. 246-248; Mansell, 1995, pp. 44-45).

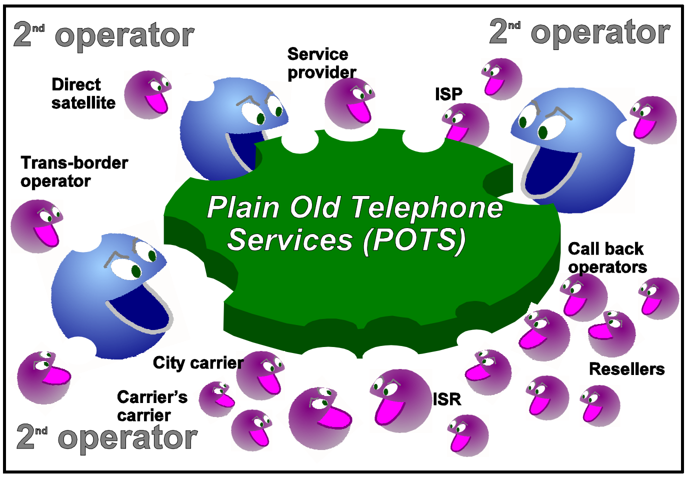

Figure 51 *The telecommunication market after liberalisation*
Source: DDV/Ministry of Economic Affairs, 1999

Liberalisation has opened new markets and many new companies have entered that market. KPN Telecom has built 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 Transport, Public Works and Water

Management reveals that companies have invested approximately six to eight billion guilders in the infrastructure. The Dutch infrastructure is known to be the most reliable network in an international comparison of telecommunication services [9] (Ministry of Economic Affairs, 2000a).

Despite the gradual steps towards full liberalisation of the telecommunication market, and despite entrance of several new players, KPN is still the most dominant player on the Dutch telecommunication market of 2001. Yet, competition is increasing and KPN is gradually losing ground to new service providers. In the consumer market it still had a 85-95% market-share[10] in 2000, but this share has already decreased to 75-85% in 2001. In the market for international telephony it kept its share (55-65%), but in the market for fixed to mobile as well as in national telephony it lost market shares to its competitors (from 85-95% in 2000 to 75-85% in 2001). This is especially due to the entrance of carrier-select companies. Yet, KPN's share of the local market is still exceptionally strong (95%) (OPTA, 2000; 2001)

Usually new telecommunication companies first try to get access to large business and industries. For that purpose large local infrastructures are built in the Amsterdam (south-west) area, where one can find a variety of industrial headquarters, financial and business services and Internet-companies. Recently many of these network companies have extended their market to small and medium sized companies, retail, but also to private customers. The Netherlands had 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.

	Existing companies ↓	**New entrants**				**Exit firms**
Categories	**'97**	**'98**	**'99**	**'00**	**'01**	**'01**
Suppliers of a public telecommunication network	95	5	12	56	22	14
Suppliers of lease-lines	62	4	4	20	10	11
Suppliers of public telecommunication services	193	7	4	102	43	32
Suppliers of a broadcasting network	92	1	14	5	3	10
Suppliers of a system with limited access	15	n.a.	3	4	0	2

Table 34 *New firms and exit firms in the Dutch telecommunication market*
Source: Market monitor 2001, OPTA

9 In this study the Netherlands was compared with the following countries: Australia, Canada, Germany, Finland, France, Japan, Singapore, the UK, the US and Sweden.

10 Market shares are presented with intervals of five percent (OPTA, 2001)

The dynamism in the telecommunication market has been exceptionally vivid. Many new companies have entered the market, with a range of activities. Growth was particularly strong in the year 2000, but the number of new entrants in 2001 was already much smaller in the case of network-suppliers as well as in the case of service suppliers. The number of exit-firms has been substantial in 2001. This gives reason to believe that in 2001 a ‘shake-out’ has taken place in the Dutch telecommunication market (OPTA, 2002).

6.6.2 New products and services

The most important developments of the nineteen nineties have concentrated in the field of increasing data-communication and the introduction of mobile communication.

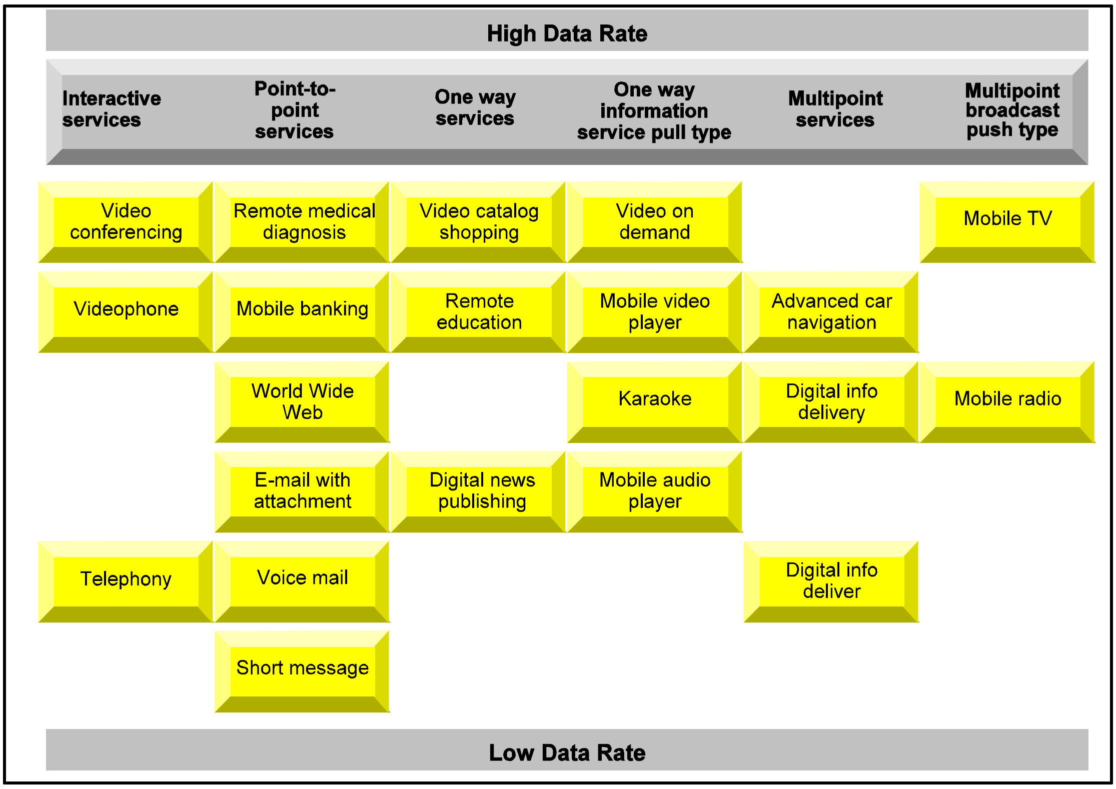

Figure 52 *Classification of applications as seen by NTT DoCoMo. Applications are classified in terms of bandwidth (from low to high data rates) and the nature of the communication (interactive, point to point, one way, pull services, multipoint and broadcast.*
Data provided by Alcatel/NTT DoCoMo, 2002

Data-communications

It is expected that the increase of data-transmission will follow US-developments. Currently the capacity doubles every fourteen months. It is also expected that the telecom-operators will extend the capacity of their networks to upgrade the existing networks or to build new ones. The operators will especially build new ‘city-rings’, to allow easy access to high speed networks. Much of these developments will be carried out by KPN, but it is also expected that new, specialised operators will enter the stage, specialising on new fields, such as high speed/high capacity infrastructures.

The cable-companies have already extended their activities to full-service companies, providing a broad range of services in broadcasting, multimedia (TV on demand, high speed Internet access) voice communication and data communications.

Mobile communications

The Netherlands has been rather slow with the introduction of mobile communications. This was partly caused by a hesitant and protective government attitude, partly by insufficient awareness of the economic benefits and partly by the positive effects of competition upon overall productivity and efficiency levels (Slaa, 1993).

KPN/PTT has been relatively slow to realise the market potential of new mobile services. The reasons 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, p. 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 profitable 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 opposed, because it regarded the burden much too high for an infant industry. It also 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 for mobile services. 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-charges and inter-connectivity demanded solutions, and it has taken considerable time to solve these problems. 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 (Hulsink, 1996, p. 260).

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[11] Five consortia have been 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).

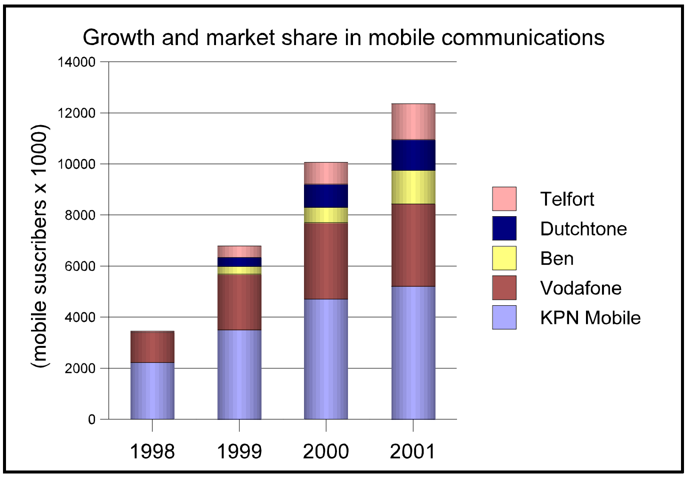

Figure 53 *Network connections in mobile telephony in the Dutch market, 1998 - 2001 (thousands) and market-shares of each provider*
Source: Market-monitor Telecom 2001, Opta

Yet, 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, which started in September 1998, and Ben and Dutchtone, each starting in February 1999.

Growth has been strong ever since. By 2001 more than 75% of the Dutch population had a mobile phone. It is however to be expected that growth will slow down. First, mobile telecommunication is reaching its point of saturation and second, growth is slowed down by the expected market-entrance of GPRS and UMTS (OPTA, 2001).

The two biggest players, KPN mobile and Libertel/Vodafoon, 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.

It is expected that data-processing and mobile communication will further integrate in the near future, which implies an integration of mobile networks and data-networks based on Internet Protocols (IP-networks). This new technological environment can be characterised as a broadband network, able to transmit at 2Mbit/s. Parallel to this new UMTS environment it is to be expected that the last mile, from the distribution point to the subscriber’s premises will be subject of further innovations. There are basically three options, high-speed modems on the last mile (ADSL), glass fibre until the subscriber’s connection point, or to make a wireless connection (Wireless Local Loop - WLL). Especially the latter technology is very promising, because it can provide broadband connections at relatively low prices. However, decisions on what direction to choose, have not been taken yet.

6.7 Implications for telecommunications research

The introduction of digital elements in the telecommunication network has provided a cost-effective alternative for the classical electromechanical switching systems. Digital services allowed for higher speed, larger capacities, and a much wider range of services. Digital services were not only cheaper, but also more advanced, and able to be tailored to customers’ demand.

If we compare the classical, monopolised setup of the telecommunication system with the current setup, we find a range of differences. On the side of the operator we find, next to the dissolution of the national monopoly, several new service providers offering a range of specialised network and customer services. On the side of the industry we find a pattern of differentiation and specialization, leading to increased complexity and new dependencies within companies as well as between companies. We also find new dependencies between the industry and the operators. In this section we will discuss how the setup of research activities has changed since the introduction of digital equipment in the public telecommunication network.

6.7.1 The setup at the introduction of digital equipment

Until the nineteen eighties we find the national telecommunication industries closely tied to the national monopoly. Dutch telecommunication research basically rested on three pillars. The first pillar was the industry, where we find Philip's Physics Lab (Philips NatLab) for basic research and the research department of Philips Telecommunication Industry (PTI), which was mainly involved in applied research and product development. Here we also find the telecommunications laboratories of NSEM[12] and Ericsson. However, these laboratories were not so much involved in the development of new ideas and new lines of equipment. They were rather down-sized replicas of the telecommunication laboratories in the respective home-countries basically meant to adjust equipment to local circumstances. Much smaller we find the research departments of the Dutch cable-industry[13]. The second pillar of the research structure is the operator's laboratory: PTT's Dr. Neher Lab (DNL). This laboratory initially started with high ambitions, but soon found out that its main task was in the design of PTT's telecommunication network. Yet, the DNL had an important role in the training of high ranked executives and the exploration of new technologies. DNL researchers were indeed very active exploring the properties of new technologies, but these activities were rather meant to make the right purchase-decisions than to develop industrial products. If however, an invention was made, it was customary practice to grant the licence to Dutch industry. The third pillar under the research structure were the university, where we find the Technical Universities of Delft, Eindhoven, Twente, and parts of the University of Amsterdam, especially its mathematical department.

6.7.2 AT&T reinforces a linear setup of research activities

The tight knit of the monopoly-like research system changed dramatically when Philips stepped into the joint venture with AT&T to introduce the 5ESS digital exchange in the Dutch telecommunication network. Almost instantly the character of research changed. The main task of the AT&T researchers was to adjust the 5ESS to local conditions. In that sense it was an instant step from an independent telecommunication research lab, with relatively much elbowroom, to the properties of a down-sized replica, with limited elbowroom. Henceforth, the core of telecommunication research for switching equipment was in the USA (the joint venture APT), in Sweden (Ericsson) and in Belgium/France (NSEM). What rested for the Netherlands were several niches, especially in transmission-technology. The Netherlands had a particularly good reputation, because it was very experienced in the production of subsoil cables.

Philips has been an advocate of a linear setup of research activities. Nevertheless, throughout the years many informal relations were established between PTI and DNL researchers. Often researchers from both laboratories were mutually involved in research projects and easily shared information. Thus, even though Philips research approach was mainly science-driven, the close links between researchers in the field provided short links to market developments.

Yet, the joint venture APT almost instantly many cut-off the many close and informal links

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[12] NSEM was taken over by ITT. Later it was part of a large merger into Alcatel.

[13] The cable industry was not so much involved in telecommunication as such. It was rather a wrapping industry, rather focussing on matters as waterproofness, coating, flexibility, than on transmission capacities.

between PTI and DNL researchers. Decision making was centralised to AT&T's headquarters in the USA. This strategy reinforced a linear approach towards the setup of research activities. The AT&T approach of research was especially science-driven, and beared the hallmarks of a classical bureaucracy.

This has been a bitter experience for many PTI researchers. Until then it was common practice that decision making was rather decentralised. This was not so much the result of an intended strategy, but rather the result of grown practice. On the one hand it was the result of Dutch management practice with its typical preference for low power distance between managers en employees. On the other hand it was partly the result of a sense of animosity between PTI and NatLab researchers. PTI researchers put great pride in their products, but often felt belittled by NatLab researchers. No doubt, Philips NatLab researchers had a high reputation in the scientific world and they were welcome guests in leading laboratories, but the radiation of success gave the NatLab researchers an almost untouchable status in the Philips organisation, and this was painfully felt by PTI researchers. They felt that they were the real experts in telecommunication, while NatLab researchers had to divide their attention between lightning-technology, consumer products, components and semi-conductors, industrial electronics, medical systems and telecommunications. Thus, solutions were rather sought within PTI own research structure, than with their colleagues from NatLab. This has led to the typical situation that many ties with their primary customer (PTT) were stronger than the ties within the Philips organisation.

6.7.3 PTT research: increasing importance of services

AT&T's approach towards the setup of research activities has changed the basic structure of telecommunication research structure, not only for the industry, but also for PTT's DNL. By relying upon its own resources, it forced PTT's DNL to face a totally new situation. First, it could no longer play the role of an (informal) colleague in the cooperation with its main supplier (APT). Yet, a new role as a customer had not crystallised by that time. Second, government had set out a new course towards deregulation, privatisation of the monopoly and liberalisation of the telecommunication market. Third, new technologies were under construction. Digital technology was already used in transmission technology, and digital switching technology was underway. Optical fibre technology showed high prospects, but still had to be integrated in the network. Fourth, during the course of the nineteen eighties it became clear that the future tended towards a separation of services and technology. This rather changed the perspective for DNL during the nineteen eighties; its future was rather in service-research than in technology.

Partly as a result of industry's withdrawal from close cooperation and partly by the tendency towards regulatory reform, the operator was thrown upon its own resources, and was preparing a switch from the classical technology-orientation towards a more service-orientated approach. But rather than strengthening the classical, linear setup of the idea-innovation chain as industry had done, the operator bended over towards a more customers-oriented approach. The market for telecommunication services was increasingly important as a starting point for innovation. Technological innovation was rather a vehicle for service innovations than an end itself.

6.7.4 New role for knowledge institutes in telecom research

The third pillar of the telecommunication research structure has traditionally played its role in the background. The universities were rather interested in technological and scientific progress, than in applied technologies. Their role was in pioneering research and education, rather than in industrial research. The latter was regarded to be the domain of industry and the operator.

Traditionally the Delft Technical University played the leading part in the telecommunication knowledge structure. For long it had been the only technical university in the Netherlands. However, two new technical universities were established in the post-war years: the Eindhoven Technical University (est. 1954) and Twente Technical University (est. 1964). These universities played an increasingly important role during the nineteen seventies and eighties. Eindhoven developed a specialism in optical technology, whereas Twente specialised in system-management, mobile technology and telematics. The mathematical department of the Amsterdam University provided important inputs for switching algorithms, and each of the universities had its own contacts especially with the DNL. Several DNL researchers held a special chair at the universities, which was an intended policy of PTT.

It goes without saying that telecommunication research at universities was also liable to the process of differentiation and specialization that had gained momentum with the introduction of digital technology. University research developed several new activities which could be used as building blocks in the telecommunication infrastructure.

A new shoot on the telecommunication research tree was the foundation of the Telematics Institute (TI). It started its activities in the field where telecommunication and information technologies overlap. The structure of the TI is an example for a new approach of telecommunication research. It was set up as a platform for discussion, development and research, to be used by the industry, the operator and knowledge institutes themselves. The TI aimed at the developments of projects in which industries, operator(s), knowledge institutes and customers could participate. The results of these projects were demonstrators, scientific papers and other research output. This idea fell in fertile ground and the Ministry of Economic Affairs, the knowledge institutes and industry participate in the institute's basic funding (60%) The rest (40%) of the budget is supplied by the organisations that participate in the institute's research projects or other parties that have an interest in a particular strain of research (customers). The TI is especially active in pre-competitive research.

6.7.5 New areas of research: the dissolution of the linear system

This was the situation as it was to be found at the eve of the privatisation of PTT into KPN in 1989. Industrial research in switching technology had almost disappeared. The industry's laboratories had all developed into down-sized replicas of the mother-companies. After Philips had withdrawn from the joint venture APT, AT&T continued its activities as AT&T/Network Systems International and later, in 1996 as Lucent Technologies. Ericsson was increasingly mastering the particular characteristics of its own digital switching system AXE. NSEM was shut off from public switching, but specialised in other fields, such as system-management.

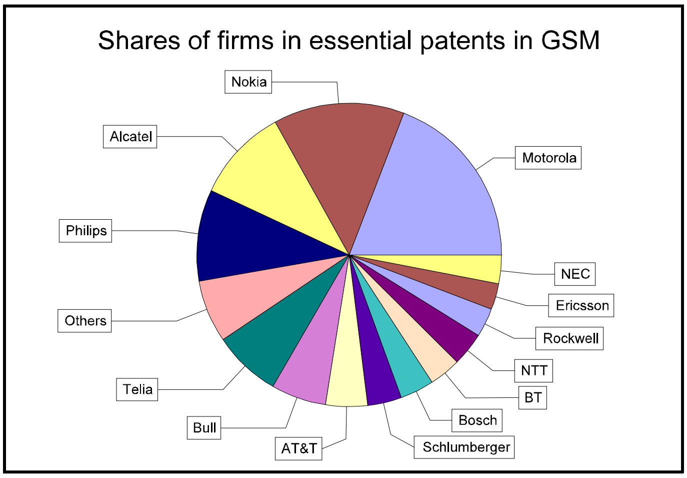


Figure 54 *Shares of firms in essential Intellectual Property Rights (IPRs) in GSM technology*
Source: Bekkers, Duysters and Verspagen, 2002

Philips was no longer active in public switching, but remained active in several other fields of telecommunication. Building on the work of its German telecommunication laboratory PKI it held several important patent rights for GSM technology. However, in the early nineteen nineties Philips totally withdrew from public telephony. Later in the nineteen nineties when the success of GSM technology had become obvious, it tried to enter the top three in the GSM handset market, but woefully failed (Bekkers et al., 2002, p. 1153)

Philips role today is mainly in the production of components and semi-conductors for telephone sets and base stations. However, the strategy to set up research activities has changed. The point of departure is no longer solely determined by the state of technology, but rather a mixture of market and technology influences. Take for instance the development of a chip in a telephone handset. For the producer of a handset it is very important to have as few components as possible, because each component is a possible source of failure. Furthermore, few components allow for small and lightweight equipment. Philips, as the producer of components, can only embed the necessary software in that particular chip, if it knows what the customer wants. Thus, in the development-path of a particular chip, a task force of producer and user(s) set out the basic properties of the chip. Users's demand is the starting point for action, rather than technological progress. In this example we find that the classical linear model is superseded by the interactive model of innovation (cf. Rothwell, 1994).

Similar trends can be observed in other field of telecommunication research. We already recalled the role of the Telematics Institute as a platform for joint research efforts. Its role is to explore the basic starting-points and develop a virtual platform for pre-competitive research. Such initiatives bring together the technological skills of the telecommunication industries with the highly specialised demands of the business community.

6.7.6 Business systems: a model for user/producer interactions

The trend can also be observed in business-systems research. Philips used to be the privileged firm under the sheltered conditions of the national monopoly. Yet, the opening of the equipment market allowed several new industries to enter the stage. Next to Philips Sopho system, Siemens introduced its Hicom system, Nortel its Meridian system, Ericsson its Vox 6110, Lacis its CSS Lacis system and Lucent its Lucent system. All these systems could be tailored to size and most of the systems were based on a system of modules. Initially these systems were provided off the shelf. The sales-officers visited the firms at regular intervals and jotted down the orders for new modules. The setup of the idea-innovation chain was rather classical, rather pushed by technology than pulled by markets. As a result, research departments were rather ignorant towards customers' demand and slow on innovation. Initially this was highly appreciated by the customers, especially the big established customers like banks, insurance companies, hospitals, etc., favoured this approach. These customers took a rather conservative approach towards technological innovation and feared that technological innovations could not provide the reliability of services that were needed for financial transactions. However, other customers were true advocates of technological innovation. Especially the small, high tech firms with contacts around the globe were eager to use different telecommunication structures. These small companies were in favour of telecommunication services based on the Internet-protocol (IP). This could not only lower the costs of connectedness, but also integrate voice and data-services.

Most laboratories thereupon changed their strategy. Philips for instance cleared several laboratory rooms and set up a demonstrator based on IP technology. It invited customers to visit the demonstrator and discuss its properties with the telecom engineers. It also offered the opportunity to install a demonstrator at the customers' premises to build up knowledge about habits, demands, routines, etc. Providing technology is one, but using the technology in daily routines is quite a different thing. This new approach radically changed the setup of the idea-innovation chain. The market was an increasingly important source of information and new tailor-made business systems were developed.

> Several researchers at Philips Business Systems were shocked by this new approach. Telecommunication research used to have a strong, inner-oriented attitude, and used to behave accordingly. It was no exception to see a researcher walk the corridor in stocked feet, shoes neatly 'parked' under his desk. Social codes used to be informal, dress codes casual and ties were pretty rare.
> The decision to clear several laboratory rooms and invite customers, made researchers insecure and shy. They were not used to have strangers looking over their shoulders. They worried about the loss of informality and a recurrent question was: *'Should I ware a tie!?'*
>
> *Philips interviewee*

Box 28 *Should I ware a tie........!?*

This structure of suppliers and users working together was strengthened by the foundation of the association of (large scale) telecommunication users (BTG). The BTG organised conferences, negotiated bulk-contracts, and set up user groups for the most popular business-systems. In BTG we find a wide selection of business and industries, ranging from universities to hospitals and from chemical industries to banks. The only requirement for membership is that the company/organisations devotes more than 5 million guilders annually to telecommunication services.

This structure has developed in the nineteen nineties and has crystallised in working arrangements, wherein industry and customers work side-by-side to tailor systems to the customers specific demands. Operators increasingly participate in these platforms. Traditionally PTT/KPN was the sole supplier of business systems, but throughout the nineteen nineties, many new operators have joined this structure. As a result, the classical sequential approach has almost completely vanished and a new approach has been adopted, rather similar to Rothwell's interactive or coupling model of innovation, often working as the flexible model of Kamoche and Cunha (chapter 2, section 4.3).

All in all the research structure in business systems has led to a new type of researcher, who is rather a consultant than a classical technician. Installing a business system is one, but implementing a system to the degree of internalised behaviour of the organisation members is quit a different thing. The consultants have basically a double agenda. On the one hand they provide after-sales services in implementing the system in the business environment. But on the other hand they are the eyes and the ears of the telecommunication industries and are able to provide the input for further development. However, rather placing them in a logical series of research activities, they are the trait-d'union between suppliers and users. Much of the research capacity of the Dutch telecommunication industry at the turn of the century is involved in these types of consultancy-activities.

This model, which was developed in business systems is also the prevalent model in mobile communication and in fixed line communication, although it certainly has not the degree of sophistication as it has in business systems. The most common procedure is that suppliers of mobile network equipment discuss new services with the mobile service providers in international user groups. A new service is only developed if the (financial) bearing-surface for such a new service is large enough to develop that particular service. Here again one can find customers and industry strongly intertwined in research activities.

Initially, operators specialised in the development of new services, while industry specialised in the provision of hardware. However, digital systems are provisional systems, in that there are constantly updated and modernised. The flexibility of digital systems is much larger than the industry and operators have ever thought in the nineteen eighties. This has certainly blurred the division of labour between industry and operators. Initially it was thought that the industry would supply the hardware, while the operator would provide the software/services. However, in the current systems the industry provides both, hardware, as well as software. The operator's task is to market the services and do the accounting.

6.7.7. Research in telecom niches

Some of the classical telecommunication firms have developed interest in specific niches. Ericsson for instance has developed special expertise in mobile communication. Its Twente laboratory, set up in the close vicinity of Twente University, has specialised in mobile technology. The standards for DECT (wireless fixed-line communications) are developed in this particular laboratory. Another example is the 'bluetooth' technology for wireless communication between computer-parts (keyboard, mouse, printer, network), but also between computers and other digital equipment (mobile phone, hand-held organiser, etc.). Lucent (formerly AT&T) has specialised in optical transmission in its Houten laboratory. In Twente it opened a new laboratory at the science and business park, which specialised in middle-ware applications. Alcatel specialised in system management. These niches were very promising at the turn of the century, but the promising perspectives have waned after the collapse of the telecommunication market. Lucent has decided to close its Houten laboratory and Ericsson has hived off its Twente Eurolab. All the bigger industries tend to concentrate research efforts in their home-countries or in countries that have the size and scope for promising research, which supports van Tulder's concept of the small country squeeze.

In this same context we can see KPN's research activities. As noted before, KPN has gradually hived off its technology orientation, and increasingly concentrated on service research. It employed a broad-focussed laboratory with approximately 350 researchers. In 2002 it has decided to hive-off its research branch to the Dutch Organisation for Applied Research TNO. KPN lacks the size for successful research activities.

6.8 Conclusion

Do national-sectoral systems of innovation exist? Are they a reality and do they matter? These were the leading questions for the previous chapters in which we discussed historical developments. Based on the evidence provided in chapters four and five, we concluded that the sectors under review had indeed persistent patterns of innovation, regarding the organizational structure of research activities as well as the institutional environment which provides sectoral resources such as regulation, finance, and the generation and dissemination of knowledge. In the historical chapters we identified two major sources for change. The first appeared as the logic result of an increasing scale of production, which led to an increase in the division of labour. As a result, research was separated from production and this has led to the typical sequential organisation of the idea-innovation chain. This process leading towards a more complicated division of labour had already started in the early twentieth century, but especially gained momentum in the nineteen twenties/thirties. The second source for change was the increasing government-interference with the economy. This process had already started during the crisis of the nineteen thirties. It gained momentum in the post-war reconstruction, but hardly lost any of its relevance until the nineteen eighties. Planning was the key word for a controlled economical development and this has strongly influenced virtually every sector of the economy, as well as people's private lives. Government held for instance a tight grip on the housing market, but it also controlled prices and wages centrally. In the telecommunication-sector it was often felt as if government was on the driver's seat in stead of PTT's own management.

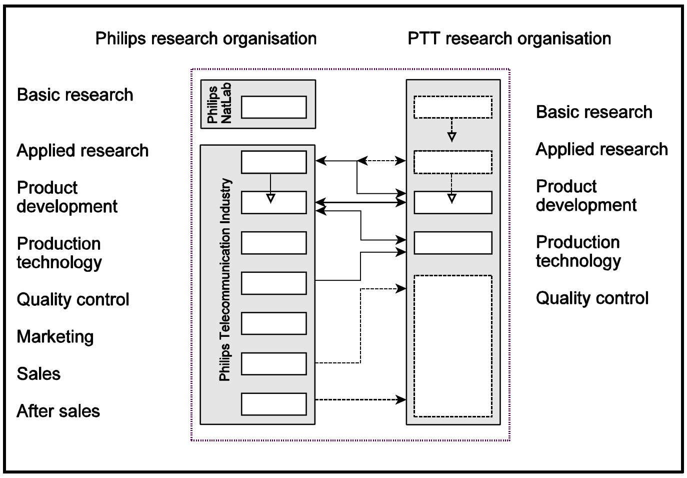


Figure 55 *Structure of telecommunication research around 1975*

The central theme for this chapter is how the telecommunication sector has reacted to the change of the technological paradigm, especially how the organizational structure of research activities has changed.

In the mid-nineteen seventies we found the structure which is depicted in the graph opposite. The Philips research organisation was a typical example of a technology push system, whereby innovation was rooted in basic research. Projects were only handed over to the next department in line, if the project had finished its earlier stage of development. Interaction between departments was however very limited. Philips' research process was a typical example of a relay-race (Metze, 1991, pp. 142-5; cf. Kamoche & Cunha, 2001). The PTT research organisation had a slightly different sequence of research activities. It was hardly active in basic and applied research and its main task was scanning the market for new technologies in the context of product development. Research and implementation were separate functions, but the ties between the two functions were rather strong.

The Philips and the PTT research organisations were basically complementary functions, mutually dependent in several fields. Philips could only develop equipment under the condition that it was PTT's fist supplier. PTT engineers could only solve technical problems if they closely cooperated with the Philips engineers. Thus, the ties between the two main players in classical telecommunication research were often stronger than the relations within the company.

The change of the technological paradigm shook up the blankets radically. The tight, complementary relations between the telecommunication industry and the operator vanished like snow in summer. The classical idea-innovation chain in telecommunication, with switching technology at the heart of the system, broke up in several new chains, each with its own dynamism and dependencies. Hardware research virtually disappeared from the Netherlands, but a new field emerged, especially in the field of middle-ware and software.

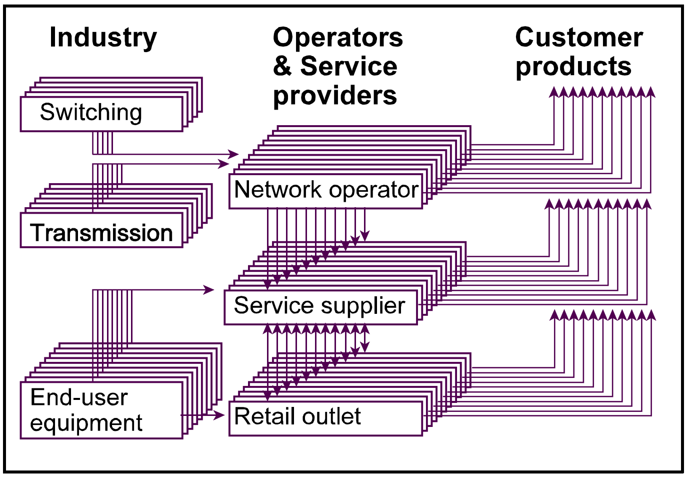


Figure 56 *Business structure in modern telecommunication with industry, operators, service providers and retail-outlets in open competition*

The change towards the digital paradigm caused a shake-out in the telecommunication industry. In 1980 there we still 27 large telecommunication industries, but this number decreased to just ten in 1990, due to mergers and take-overs (Roobeek and Broeders, 1993). However, the liberalisation of the telecommunication market was an invitation for many new companies to enter the stage, some with high-pitched ambitions to become the second operator, others with the ambition to conquer specific niches. Competition increased. The customer could choose from an ever expanding range of products, technologies and services, offered by a range of suppliers. The business structure in telecommunication changed dramatically. Stable relations, one supplier, few products and few services marked the classical telecommunication market. The combination of technical change (digitalisation) and regulatory change (liberalisation) created volatile business relations, many (new) suppliers, many new technologies, products and services, and fierce competition.

The idea-innovation chain in telecommunications used to be a linear process, characterised by purposive rationality. It was highly predictable in the stable environment in which the national telecommunication companies and the national operator functioned in a monopolised structure. Their mutual goals were to achieve maximum efficiency and to reduce uncertainty. Tight control of operational guidelines and a structured innovation process, with discrete phases which were carried out sequentially characterised this classical process. The metaphor which is often used is the relay-race. The heart of the system was the switchboard. All additional technologies were adjusted to, and all services were limited by the performance quality of the switchboards.

How different the situation in modern telecommunication! The heart of the system today is a high-pitched specialised computer. Its characteristics are not so much in the hardware, but in the software. This offers much more flexibility and dynamism, because software can (relatively easy) be adjusted to the meet the requirements of the network-operators and the service providers. Digital switching technology provides a general connection-platform on which a range of additional services can be developed. Middle-ware applications are built on these general connection platforms to establish an additional technological platform for specialised services. It is obvious to see that the process-industry demands a different technological platform than the financial world, air-control systems, or on-line shopping. Within the general technological outlines of middle-ware solutions, software-developers can build specific software solutions, carefully tailored to the need of individual customers.

Industrial hardware-research has virtually disappeared. The general connection-platform is extended and maintained with off-the-shelf equipment and adjusted to local requirements by its suppliers. The heart of telecommunication research is currently concentrating on middle-ware solutions. Here, the large telecommunication industries play an important role, next to the larger operators, specialised industries, research institutes and universities. In software-solutions we also find the large telecommunication industries, especially in software-development for business-system research. But here we also find numerous entrepreneurial software-firms especially active in Internet solutions.

Yet, none of the research processes in middle-ware and software is to be characterised as a purely linear process. Central in all the research-process is an orientation on marketable solutions. Users and producers are jointly involved in the definition of basic characteristics of new technologies, products and services. Networking in pre-competitive research is rather the rule than the exception. The actors in this process embrace change, because it creates new business-opportunities. Given the fact that the innovation process is expensive, the producers and users use their relations to absorb uncertainty. This is mutually beneficial. Producers can scan the market and can make a calculated-venture for business-opportunities. Users can bend the innovation towards their own demand and negotiate favourable conditions. Thus, responsiveness, flexibility and adapting to changes are central in the innovation process. Close cooperation between producers and users limits the risk to back on the wrong horse. Search processes, which are inherent to the innovation process, can fast converge towards broadly accepted solutions. This type of research process is far more flexible than the classical, linear process of innovation.

In the development of middle-ware solutions we find a slightly different structure. Within the limits of technological templates for specific field (finance, shopping service, process-control, (air) traffic-control, etc.), the actors improvise to find suitable technological solutions. Experimentations, discovery and unrelenting innovation are key in these processes that lead to progressive convergence within minimal structures. Kamoche and Cunha addressed this latter type of innovation with the metaphor of jazz-improvisation.

The shift of the technological paradigm has loosened the ties between the classical actors, and involved new actors to participate in innovation. The majority of these research projects are set up as network-like structures. Different resources and field of competence are combined to find suitable technological solutions. These network-like structures are beneficial for all the participants, because they increase the scale and scope of activities, through the combination of different technological competences, the sharing of risk and an improved ability to deal with complexity. However, constituting networks is a delicate undertaking, which requires a careful balance between competition and cooperation. Research institutes, such as the Telematics Institute have an important role in the brokerage of network-relations. The institute delimitates the borders of the research subject. It approaches possible participants and invites them to join the network. The institute also delimitates the time-period. This latter element is important, because it allows companies to choose the time and subjects in which they are willing to invest. We will discuss the role of such bridging organisations in greater detail when we come to speak about institutions (chapter 8).

The shift of the technological paradigm has marked the end of a genuine Dutch telecommunication industry (Philips), but it has also marked the beginning of a new era in telecommunication research. Lucent (formerly AT&T), KPN and Ericsson have been especially active in telecommunication research (software, end-user equipment, transmission). However, the collapse of the telecommunication market has marked the advent of another era. Ericsson closed its Euro-Lab in Twente, Lucent closed its Houten Laboratory and KPN hived-off all its research activities to the Dutch organisation for applied research (TNO). It seems as if van Tulder's concept of the small country-squeeze has proved its relevance once more. Large companies concentrate their research capacities where they have the size en scope to be competitive in the large world-market.

Chapter 7 Change of the technological paradigm in modern biotechnology

7.1 Introduction

Major discoveries in biotechnology have lived a rather sheltered life, before the impact of radical new approaches in biotechnology came floating to the surface. Crick and Watson's discovery of the double DNA structure in 1953 was in fact such a radical discovery, that has put genetic research high on the agenda. The break-trough came however, in 1974 when researchers managed to insert strings of DNA from one organism into another, thus changing the genetic structure of that organism.

At first sight this was nothing new. Plant and animal breeders had in fact done so for ages. They tried to improve the characteristics of plants and animals by breeding and cross-breeding until the desired characteristics were present in the offspring. For instance, the ancestor of today's sugar-beet was a puny plant that grew in the dunes and was only known to the few who that had learned to appreciate the sweet taste of its root. This tiny plant does hardly resemble the bulky sugar-beet as we know it today. The sugar-beet is the result of several centuries of breeding and cross breeding.

Although the results have been impressive over the years, there was a natural limit to the attempts to refine plants' or animal's characteristics. In their attempts to improve the characteristics of plants and animals, the breeders were limited to the use of related organisms. Such classical breeding technologies are usually captured under the term classical biotechnology. This broad term refers to several techniques which are used in traditional breeding and agricultural cultivation practices. These techniques have a long history in developing native micro-organisms, plants and animals, into strains for producing foods (e.g. bread, wine, beer, cheese and yoghurt) or medicine (antibiotics). Classical biotechnology also includes the application of enzymes and micro-organisms in food-processing and the use of modified biological compounds to alter the metabolism, such as in the production of flavouring substances.

The term 'biotechnology' was used since the nineteen twenties to point at the use of biological systems and/or living organisms (or their derivates) to create products. There is however, a distinction between classical biotechnology and modern biotechnology.

'Modern biotechnology' refers to a particular set of techniques used to genetically modify (or 'genetically engineered') organisms. The modern biotech toolbox contains several in vitro DNA recombination techniques, as well as direct injection of nucleic acid into cells and their organelles. In short, the introduction of genetic material from one species into another. Through the use of recombinant DNA techniques, modern biotechnology is changing the way that strains of micro-organisms, plants and animals are developed and used. The characteristics of modern biotechnology include the capacity to transfer genes between completely unrelated species (and to specify which genes will be transferred), and the efficiency with which new types of plants, animals and micro-organisms (and their products) can be developed (OECD, 2000a, p. 8).

The Netherlands had an excellent starting position for modern biotech research. It had a well-developed research structure in the agro-food industry that could build on the strength of cooperation between universities, knowledge institutes and industry. This research structure was especially developed in agro-industrial research, and it could be measured among the best in the World.

The Netherlands has traditionally a strong agricultural sector. Already in the golden age the yield per hectare and the yield per cow has been very high. As a result the Netherlands has a much larger annual output than one would have expected from such a small and densely populated country. The Netherlands is one of the leading dairy producers in the world with an annual output of approximately eleven billion kilos of milk. Half the milk production is used for the production of cheese. Part of the agricultural production is exported to all corners of the world, especially the fresh products from the Garden of Europe. Another part is used to supply the extensive food and drinks industries. Here we find several large industrial conglomerates as Unilever and Nutricia, but also Heineken, Grolsch and Bavaria in brewing. Closely related to the food-industry we find several chemical industries which are especially active in food-ingredients, but also in pharmaceuticals. Here we find firms as DSM and Akzo Nobel

The Dutch agriculture and food-processing sectors are engaged in a continuous process of improving the quality of their products. Research institutes conduct research into the cultivation of high quality plants designed to improve taste, appearance, nutritional value or resistance to disease. The foodstuffs and chemical sectors are engaged in advanced research into the application of modern life science processes to replace chemical process by biological processes. The fruits of the new technology are already widely used, especially in the agro sector and in medicine production (Ministry of Economic Affairs, 2002)

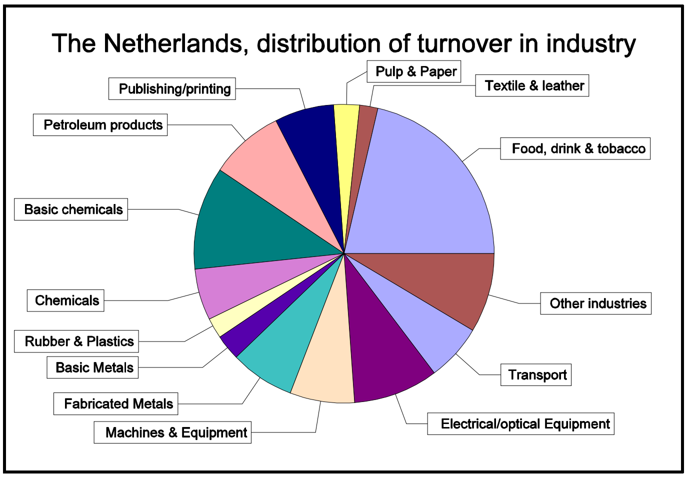


Figure 57 *The Netherlands, distribution of turnover in industry (in billion €)*
Source: Statistics Netherlands (CBS) 2002

The agro-food sector is by far the most important industrial sector in the Netherlands. The food, drink and tobacco industry represent 21.4% of all industrial turnover.

The chemical sector takes approximately another 20%, which even increases the importance of modern bio-technologies, because bio-technological processes increasingly replace the classical chemical processes

The agriculture/food sector and the chemical sector are very important export sectors. Food accounts for 14.6% of the value of Dutch exports in 2001, while chemicals account for 23.5%.

The Netherlands is the third exporter of agricultural products and foods after the US and France. Yet, despite its importance, the agro sector is reaching the end of its innovation-cycle and needs new breakthroughs to keep its position among the leading countries. Improving quality of foodstuffs, increasing nutritional value and health improving qualities are the main beacons for bio-technological research. The step from nutri-genomics, which studies the relations between food and health, to bio-pharmaceutical sciences, and pharmaco-genomics is regarded to be a logical next step in research-orientation.

With the typical setup of the Dutch industrial climate which heavily weights on agriculture and chemistry, it made sense that modern biotechnology was first applied in agricultural research to increase the knowledge on how plants, animals and organisms react to external circumstances and the role of their genetic constitution in this process. These first applications aimed to improve the breeding of plants and animals, innovations in fermentation-processes and microbic conversions, improvement of storing and transport. It also was used in the knowledge about renewable resources in industrial processes.

On the waves of this body of knowledge the field of technology broadened, especially towards healthcare. Modern biotechnology provided the tools for better diagnosis, better treatment and better preventive healthcare (cf. NWO, 2000 a,b,c).

We will start this chapter (section 7.2) with a discussion of the problems we have in measuring the general characteristics of modern biotechnology. Many indicators that are quite suitable in other sectors cannot be applied, because biotechnology is very segmented, with each segment having its own dynamism and characteristics. In section 7.3 we discuss the economical strength of Dutch biotechnology as it is assessed by knowledgeable scientists and entrepreneurs, and discuss the localisation of firms (section 7.4). Section 7.5 takes the lions' part of this chapters and focuses how economical actors have organised cooperation in the field. Section 7.6 closes off with a comparison between the telecommunication and biotech sectors.

7.2 Problems in measuring general characteristics of Dutch biotechnology

Ask an expert in biotechnology to tell you the number of biotech firms in the Netherlands. The most probable answer you will get is that s/he does not know! 'What exactly do you define as a biotech firm?' s/he will probably ask.

No doubt a firm that has specialised in recombinant DNA technology is a biotech firm, but what about a company that uses biotech diagnostic kits to detect pollution? Or, what about the PigMaP programme, meant to map dominant traits in pigs, so that a farmer/breeder can make a right match between boar and sow? Should a company that has specialised in bio-informatics also be counted as a biotech firm, or not? All in all it is not so easy to answer these questions how many firms are active in Dutch biotechnology. Take for instance the potato/starch industry.

> The Dutch firm AVEBE is constantly trying to improve the traits of potatoes; on the one hand to fight potato-diseases, and on the other to get the highest proportion of starch per weight. Classical bio-technological methods are still dominant in research. However, the classical method is very time-consuming, a process that easily takes between ten and fifteen years. Modern biotechnology provides several technologies to speed up this process and AVEBE has applied a strain of research based on the use of antibiotics-resistant genes.

Is AVEBE then, a biotech company? Yes, because it is actively involved in biotech research. No, because the core of its research activities is based on classical refinement technologies. Similar difficulties are to be found if we want to assess economic growth of the sector. From the outside this seems rather easy. Count the number of firms and each increase should indicate growth. However, it is not that simple! Firms merge as they use the advantage of scale or are taken over by cash-rich companies. The absolute number might be falling, even while growth is on its way.

What seemed so obvious from the outside, is rather complicated in practice. Size, growth, and specialization pattern in modern biotechnology are not so easy to assess. Furthermore, it is particularly complex to analyse the structure of biotech companies. Historically, the definition criteria adopted from different national and international sources have been heterogeneous. We generally build on van Beuzekom's definition, which focusses on techniques (tools, manipulation and know-how) that either modify existing living organisms/parts thereof, or transform material of living organisms or not, by the use of processes involving living organisms, for the purpose of producing new (scientific) knowledge or developing new products and processes (OECD/van Beuzekom, 2001). The following classification is referred to:

- DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering;
- Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein engineering, proteomics, hormones and growth factors, cell receptors/signalling/pheromones;
- Cell an tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation,

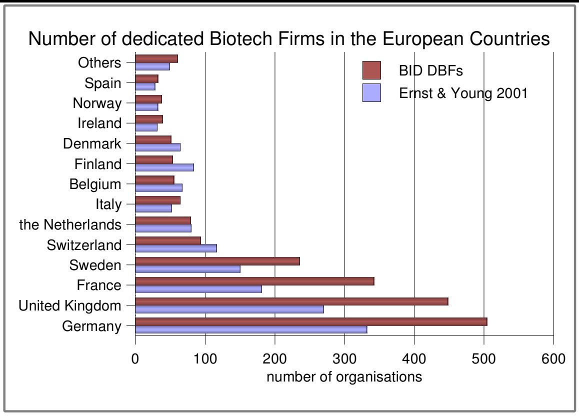
cellular fusion, vaccine/immune stimulants, embryo manipulation;
- Process biotechnology: bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurisation, bioremediation and biofiltration;
- Sub-cellular organisms: gene therapy, viral vectors.

In addition, firms are taken into account which focus on the development of tools, instruments and devices that apply directly and prevalently to biotechnology, such as bio-informatics, high-throughput screening, combinatorial and chiral chemistry.

What furthermore, complicates the analysis is that many biotech organisations are so small and young that they do not show up in surveys. Moreover, biotech companies are typically heterogeneous and embedded in complex propriety and collaborative networks. They range from public research organisations (universities, graduate schools, research labs, hospitals, foundations and other institutes) to large pharmaceutical, agro-chemical, food and chemical companies (typically highly diversified multinationals with several divisions and intricate propriety and control links). Allansdottir and her colleagues have made a distinction between:

- Independent dedicated biotechnology firms (DBFs), which are: i) core biotechnology firms and include private and public firms specialised in biotechnology products and process development, ii) specialised suppliers, e.g. firms active in combinatorial chemistry, bioinformatics, DNA sequencing instrumentation, and in the production of tools and techniques which are used by 'core biotech companies';
- Established companies active in related fields (ECs), which are large companies that have a sound position in modern biotechnology. Although the core-business of the firms in this category is not in biotechnology, they are actively involved in biotech research and development;
- Biotechnology divisions, which are units that operate in biotechnology and are controlled by established companies or by dedicated biotechnology firms;
- Public Research Organisations (PROs), such as research institutes, universities, hospitals and other public organisations with relevant scientific results in molecular biotechnology and in fields and disciplines related to biotechnology (Allansdottir, et al., 2002).

An alternative is offered by the annual 'Ernst & Young reports' about the state of European biotechnology. The unit of analysis in these reports is the ELISCO, or entrepreneurial life-science company. This definition is largely comparable with the DBF (Dedicated Biotechnology Firm), which is discussed in the above. Ernst & Young define an ELISCO as a company which uses biological techniques to develop products or services to serve the needs of human healthcare or animal health, agriculture productivity, food processing, renewable resources and environmental affairs. The term 'entrepreneurial' refers to the differentiation between the multinational chemical, agro-chemical or pharmaceutical companies on the one hand and small and medium-sized companies on the other. The typical profile of an entrepreneurial company includes the foundation by scientists/engineers, as well as venture capital backing, and a high percentage of employees working in research and development. This profile excludes industries which use classical biological processes such as the brewing, wine and cheese-making industries. It also excludes non-profit research-organisations, universities and other academic institutes (Ernst & Young, 1997).



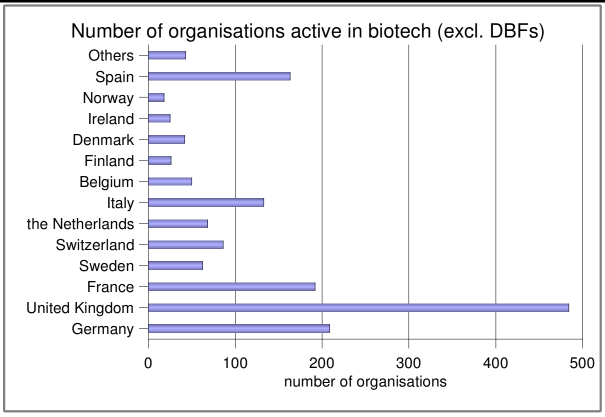


Figure 58 *(left) Number of Independent Dedicated Biotechnology in European countries*
Source: Pammolii and Ricaboni, 2001, based on BID, University of Sienna and Ernst & Young, 2001

Figure 59 *(right) Number of organisations, other than Independent Dedicated Biotechnology firms, active in biotech in European countries*
Source: BID/University of Siena

Modern 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 the 1997's listing of Ernst & Young annual reports, it was listed fifth in Europe, behind the UK, Germany, France and Sweden. In 1999 it was surpassed by Switzerland and in 2001 also by Finland (Ernst & Young, 1997-2001).

As stated in the above, Ernst & Yong's analysis has put strong emphasis on companies with a clear entrepreneurial attitude. That is why there is a marked difference between the data provided by Ernst and Young and other organisations that have assessed the biotech sector, such as the Dutch Organisation for Applied Scientific Research TNO, the biotech association NIABA, the Ministry of Economic Affairs and the European Union. Estimations reach from less than forty (Ernst & Young, 1997) to several hundred (Ministry of Economic Affairs, 1997), two-hundred ninety (Horning, 1996) or even more. These latter, high numbers will most probably refer to the number of companies that are involved in biotech, for instance, as a strain of research/production next to classical applications.

The Canadian Department of Foreign Affairs and International Trade has made the following distinction: 300 Dutch firms are involved in biotech, but only fifty-five companies have biotech as their core business (OECD, 2001). It is, however, fair to assume that around 90 companies are actively involved in biotech, of which 79 are identified as ELISCOs (according to Niaba/Biopartner and Ernst & Young), or Dedicated Biotech Firms (DBFs) (in the definition of the BID data-set of the University of Sienna).

Still, it is hard to draw a general conclusion regarding the ranking of countries. The countries that have recently surpassed the Netherlands may have had the advantage of catching up late, with better instruments and support to start up new companies. The German BioRegio programme has for instance facilitated the foundation of several new firms, but experts believe that this number will fall, on the one hand because firms do not survive and on the other, because firms merge into stronger new players.

Another factor to keep in mind is that several Dutch companies have withdrawn from biotech-research, especially in the plants and seeds-sector. The main reason to withdraw was the change of the regulatory regime. Most of the research programmes were based on the use of antibiotic-resistant gene technologies. However, government's future policy includes a ban of this particular strain of research and it is to be expected that this policy will be effectuated in Parliament. This policy has undermined several initiatives. Take for instance the efforts of Bulb Research Centre.

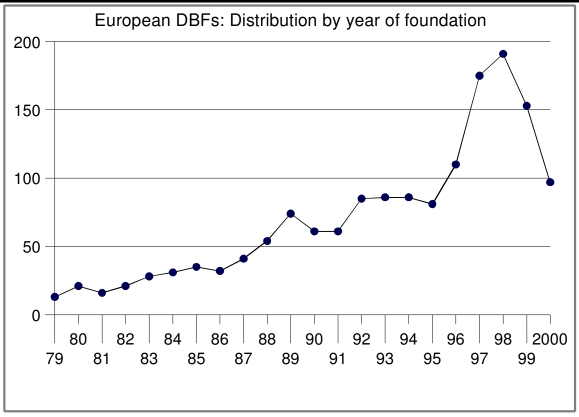
This research station for applied research (which currently has become part of the Wageningen

> University and Research Centre) had set up a programme to fight typical diseases in lilies, based on this particular antibiotic-resistant gene technologies. To get the programme on the research agenda had been quite an effort. The structure of this research centre was that plant breeders participate in decision-making and research funding. A new programme, clearly based on unfamiliar technology and with uncertain outcomes was not much favoured by the breeders. When government proposed to ban all research programmes based on antibiotic-resistant gene technologies, the breeders decided to turn back to the old familiar technologies and restrain from modern approaches.

Furthermore, several Dutch companies have been taken over or have merged. Some of these companies had substantial research activities in the Netherlands, but as a result of a take-over, a restructuring of the research capacity has taken place in some cases, which has ultimately lead to a concentration of research capacity abroad, at the expense of research capacity in the smaller European countries. Van Tulder's concept of the small-country squeeze has also struck the biotech sector in a rather similar sense that we could observed in the telecommunication industry.

> Take the example of Syngenta Mogen. This company (which was the result of a merger between Zeneka and Novartis in 2000) had managed to acquire one of the most prominent patents in plant technology, which was developed by the 'godfather' of Dutch plant research professor Schilperoord. It was a patent on altering the genetic structure of plants via bacteria in the seed-bed. The sale of the patent to such a prominent company was regarded to be the best guarantee to safeguard the patent for the Dutch biotech industry. However, only one year later Syngenta decided to close down its Dutch laboratories and concentrate its research efforts in the U.K. and U.S.A. Syngenta's research capacity had grown top-heavy through a range of mergers and therefore decided to close down research laboratories in the smaller European countries. The closure was not a direct result of government policy to ban field trials, but it certainly was not very helpful. In the words of Syngenta's managing director: 'the fact that the number of field trials has made a free fall since 1999 trough government policy was most annoyingly'.

Ranking countries on the number of ELISCOs or DBS is thus somewhat misleading. First, it easily ignores the role of private institutes, large established firms or private research organisations. From the graph above it is clear to see that the UK for instance has a large share of this type of organisations in comparison to the number of ELISCOs or DBFs. Second, it is to be expected that large countries have more companies than small countries. Thus, one should calibrate the number of DBFs, for instance by using the number of inhabitants or GDP numbers. If one applies these measures, it is clear that Sweden is ranking first according to both measures, followed by Switzerland, Ireland, Finland and Denmark. Norway, the UK, France. Germany and Belgium are mid-rangers, and the Netherlands, Austria, Italy and Spain are clearly trailing behind (cf. Allansdottir et al. 2002)



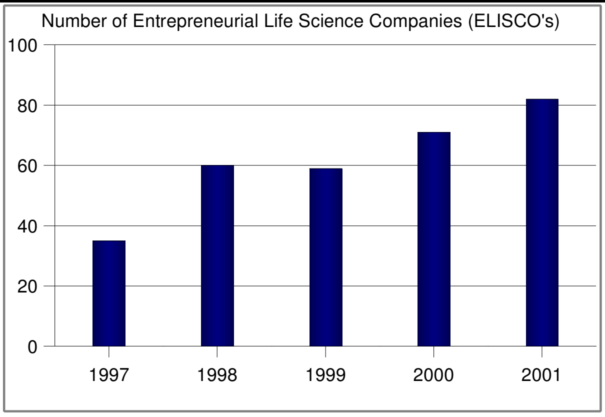


Figure 60 *(left) European Dedicated Biotechnology Firms: Distribution by year of foundation*
Source: Pammoli and Riccaboni/BIC/University of Sienna

Figure 61 *(right) Dutch Biotech Firms 1997 - 2001*
Source: Ernst & Young annual biotech reports

One has to be careful interpreting these figures. The graph above (left) gives the number of new Dedicated Biotechnology Firms from 1979 to 2000. After a gradually increasing trend there was a peak in the years 96 and 98, but currently numbers of new entrants are falling. This slowdown seems to be similar to the one observed in the US at the beginning of the nineties and it could anticipate a period of stabilisation, consolidation and selection, with mergers, acquisitions, and exit offsetting new companies formation (Allansdottir at al., 2002). This could implicate that early starting countries have already reached state of stabilisation, while other countries are about to reach their peak.

7.3 Economical strength of Dutch biotechnology

A clear-cut classification of the Dutch biotech sector is hard to give, because there is considerable overlap between fields. For instance, knowledge of plant-breeding can be applied in agriculture, but also in pharmaceutical or in chemical industry. Even though each classification system has its flaws, we will start this section with an assessment of the economic importance of five relevant sectors (food, chemicals, agriculture, environmental care and pharmaceuticals), as they are listed by Degenaars and Janszen in a report to the Ministry of economic Affairs (1996).

The food-industry is the largest of these five sectors, with an annual turnover of 75 billion guilders in 1995. This is almost as large as the joint turnover of the chemical industry, which amounts to 40 billion guilders, and agriculture with an annual turnover of 36 billion guilders. These three sectors are also the leading economic sectors in the Dutch economic landscape in the mid nineteen nineties. Compared to these giant sectors the contribution of the environmental care sector (8 billion guilders) and the pharmaceutical sector (4.9 billion guilders) in the total of biotech-related sectors, is just rather modest.

The Degenaars/Janszen report has tried to identify the strength and weaknesses of the Dutch biotech

Sector	**Estimated share of biotech related turnover**					
	1996		**2000**		**2010**	
	inside experts	outside experts	inside experts	outside experts	inside experts	outside experts
Pharma-ceuticals	9	10 (+)	20	22 (+)	34	38 (+)
Agriculture	2	9 (+)	7	18 (+)	20	38 (+)
Food	3	6 (+)	10	12 (+)	30	25 (-)
Chemicals	13	6 (-)	18	12 (-)	27	20 (-)
Environmen t	9	4 (-)	15	10 (-)	18	21 (+)

Table 35 *Experts' estimation of the share of biotech related turnover. Estimations are made by experts from within the sector (inside experts) and experts from adjacent biotech sectors (outside experts). The difference between inside and outside experts is between brackets.*
Source: Degenaars and Janszen/Ministry of Economic Affairs, 1996

industry. As part of their research they have asked experts to estimate the share of turnover in each sector that was related to modern biotechnology. The experts have made estimations for their own sector, but also for the adjacent biotech sectors. It is interesting to see that the outside-experts estimate the biotech-related share of turnover higher in pharmaceuticals and agriculture than the inside-experts. But, outside-experts estimate the biotech-share much lower in chemistry than their inside-colleagues. In food and environmental care the case is not so clear-cut. At the time of the interviews (1996) the outside-experts expected a higher share in the food-industry than their inside-colleagues, but by 2010 this has changed. In the sector of environmental care we find the reverse. This may indicate that the inside experts in the food industry have anticipated a period of fierce public resistance against biotech applications in food, but also that resistance will be waning after some time.

It is clear to see that the respondents are biassed by the dynamism within their own sector. The potential of bio-technological methods is regarded high for pharmaceuticals and agriculture, but the inside-experts know that the industries in the sectors are hesitant to apply the full potential in industrial production. This indicates that the perception of biotechnology is liable to other influences, such as the public attitude regarding biotechnology and the use of genetically modified organisms. This is definitely the case in the food-industry. Industries are reluctant to apply genetically modified technologies in their products, even though these technologies are available today. In cheese-making and brewing there are several new technologies on the shelf, but not used in production to avoid public mistrust. However, the potential of these technologies is high as is indicated by the large future share, estimated by inside-experts. It seems that the public's resistance towards the use of bio-technological methods is seen as a temporary theme.

The potential of bio-technological methods in chemistry is under-estimated by outsiders. This might be explained by a certain degree of ignorance in the life-sciences. The same might be the case in the environmental care sector.

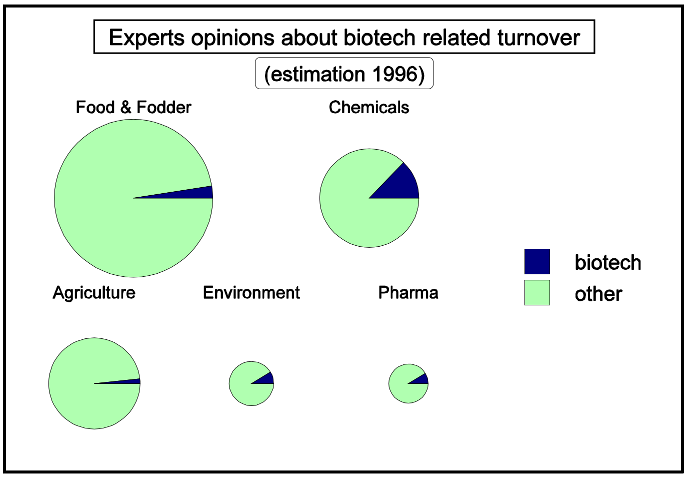
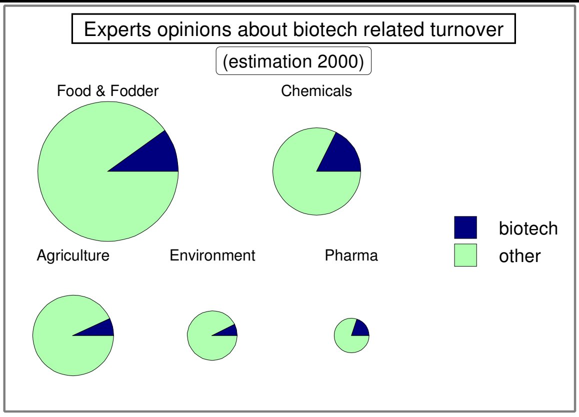


Figure 62 *Experts' opinion (from within the sectors) in 1996 about biotech related turnover. (The size of the pies reflects the importance of the sectors in the economy*
Based on Degenaars and Janszen/Ministry of Economic Affairs, 1996

In previous chapters we have mainly focussed on research in agriculture and the food-industry as the 'founding-fathers' of the Dutch system of biotech research and production. The importance of these sectors is hard to ignore, given the size of these sectors in the economy. The pies in the graph above reflect the relative size of the five sectors under discussion and it is clear to see that the potential of biotechnology concentrates in the agriculture/food/ cluster. The Dutch chemical industry is not such a clear-cut sector. On the one hand it is built on the processing of oil-based products, and on the other on the processing of derivates for the food and pharmaceutical industry. Furthermore, it has to be noted that the Dutch pharmaceutical industry has a clear specialization in animal healthcare-products and thus, has close links again to the agro-food cluster. All these sectors have clearly benefited from the research-structures that were developed under the responsibility of the Ministry of Agriculture, and that we broadly discussed in chapter five (the OVO triptych)



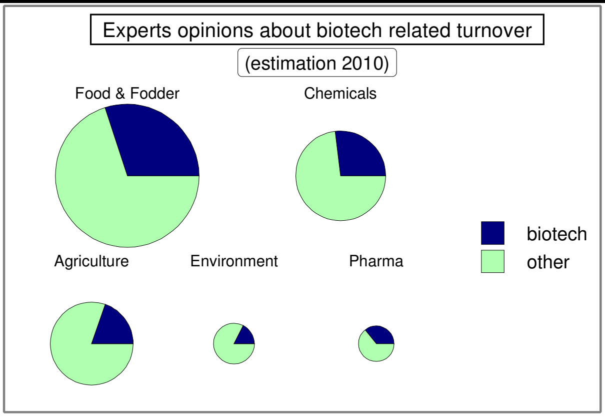


Figure 63 *(left) Experts' opinion (from within the sectors) in 2000 about biotech related turnover*

Figure 64 *(right) Experts' opinion (from within the sectors) in 2010 about biotech related turnover*
(The size of the pies reflects the importance of the sectors in the economy (assumed that the relative shares of sectors are stable over time)
Based on Degenaars and Janszen/Ministry of Economic Affairs, 1996

If we now compare the experts' estimations for the year 2000 and 2010, it is obvious to observe the growing importance of biotechnology in each sector. Let us -for the sake of argument- assume that the relative size of the sectors does not change over time and calculate the economic value of each sector.

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, because both sectors are so much smaller. The biotech share in agriculture (2%) was low, but the economic impact of biotech in the agricultural sector was comparable with those of the pharmaceutical and environmental sector. The biotech share in agriculture was also relatively low (3%), but still the economic value was much higher than the joint value of the biotech share in agriculture, environmental care and pharmaceuticals.

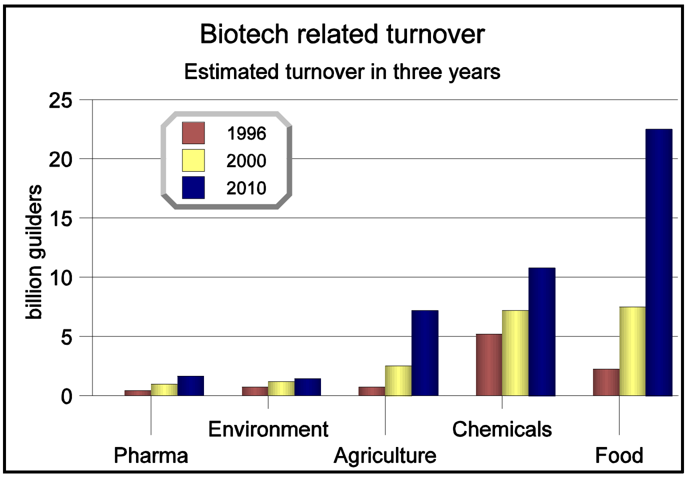


Figure 65 *Expert opinions of biotech related turnover in three years, based on a projection of 1995 turnover in five sectors*
Calculations based on data provided by Degenaars and Janszen, 1996

The experts believe that the 2010 biotech landscape will have changed considerably. From the graph opposite it is clear to see that the biggest contributions are to be expected in food, chemical and agricultural sectors. 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 shares in-between (resp. 20 and 27%).

This simple extrapolation of 1996 data has clearly excluded dynamism from each sector. It might be well possible that each sector has changed considerably during the years, and gained or lost importance. However, the graphs clearly demonstrate the line of thinking in the mid-nineteen nineties. The economic potential was thought to be most impressive in agriculture, the chemical industry and especially the food-industry, while relatively modest in the pharmaceutical industry and environmental care.

The mechanisms that stimulate, or withhold developments in each sector, differ considerably between sectors. Consumer-acceptance is crucial in the agricultural sector, but it is not the only factor. Transparency, predictability and reliability of the system of rules and regulations might open or close the window for future perspectives. It is crucial that firms have confidence in the ability and willingness of government and public agencies to admit new products on to the market.

Trust is also crucial in the pharmaceutical sector, albeit in another context. The process of bringing a new product to the market is long and extremely expensive. Crucial in this process is to win the financiers' confidence that the investments will pay-off in the future. Finance, thus, is the pivotal element in pharmaceutical research. The patent-portfolio is a company's biggest asset in this process. It demonstrates the ability of a firm to operate at the leading edge of technology, but it also is a source of income through licencing. Thus, the dynamism in agriculture/food on the one hand and pharmaceuticals on the other, is quite different and indicates that we have to be careful in predicting the future.

Nowadays we find that almost 40% of Dutch biotech firms are active in human or animal healthcare (Holland Biotechnology, 1999). Most of these firms are in the development of platform technologies, like sequence-analysis, vaccines and diagnostics, or special ingredients for pharmaceutical use. The biggest player is AKZO/Nobel, with its subsidiaries Organon, Organon Technica, Diosynth and Intervet, and Solvay Pharmaceuticals. Crucell (until recently Introgene and U-BISYS) and Pharming were two of the 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 which clearly belongs to the larger Dutch companies, most of the Dutch companies in pharmaceutical research are small and medium sized enterprises.

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

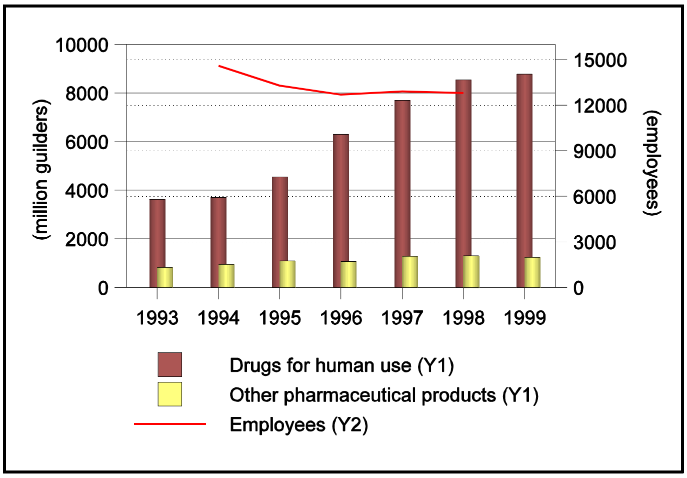


Figure 66 *Sales of Pharmaceutical production 1993 - 1999*
Source: CBS

DSM, which used to be one of the leading chemical industries is currently restructuring its industrial activities towards the life-science sector. To strengthen its position in this field, it has acquired Gist Delft (the yeast and food branch). It also acquired Crucell and thus strengthened its position to be one of the main producers of ingredients to be used in drugs.

The Netherlands may be a leading country in food and agricultural products, it is however just a modest player in the international pharmaceutical sector. (Ministry EZ/TNO, 2001). In 1998 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 in human healthcare is among the world's top-ten players.

A totally 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 world wide after Merial and Pfizer). The origine of this specialization pattern in the Dutch pharmaceutical industry indicates the economic importance of the agricultural sector and food-cluster, especially the meat-industry.

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. However, as we discussed earlier, some of these firms have recently withdrawn from modern biotech, because the future outlook is less promising than initially expected.

Dutch plant-refinement and seed companies are among world leaders. Companies like Barenburg and Cebeco, and UK/NL companies like Advanta are listed among the world leaders in seeds (IMBA, 2001). AVEBE is among the world leaders in starch-productions and the Netherlands has an exceptional good reputation in the cut-flower and flower-bulb industries. However, research in plant-refinery has experienced a serious set-back by a change of regulation. Many strains of research used to be 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 many of which were close to market-introduction.

This measure has made companies shy to develop new strains of research. Setting up a new strain of research is demanding, in the sense of investments, future perspectives, scientific knowledge and creativity. It demands a positive state of mind to set up new research. In view of the public debate regarding the acceptance of genetical modification in food and agriculture, it is the question if companies are still willing to make the effort. Several companies have (temporarily) shelved biotech research and taken a low profile, others have totally withdrawn such as Advanta. As a result, the early successes in biotech research, which have concentrated in agriculture and the food-industry, have 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 current 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 also bio-technological services. The strength and development of the market for environmental care are largely the result of rules and regulations and the Netherlands has been a frontrunner in the design of the regulatory system in this field.

7.4 Localisation of firms

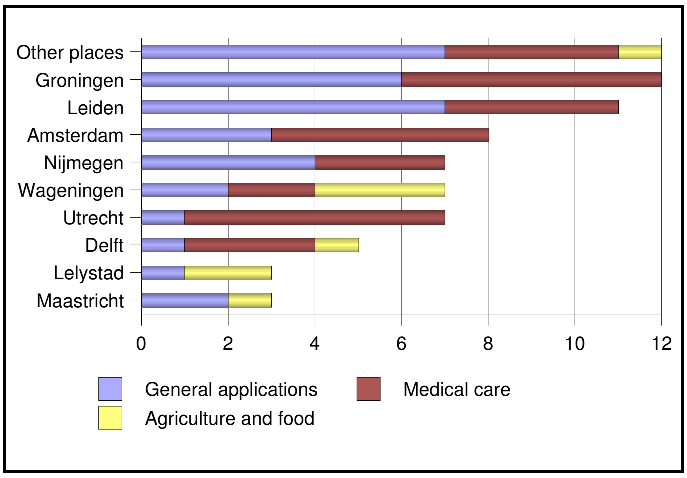


Figure 67 *Location of Dutch biotech firms founded after 1990 as clusters around universities*
Source, Biopartner, 2000

Biotech firms in the Netherlands are usually to be found in places with a University. Of all biotech firms founded after 1990 only twelve were established in places without a university. Lelystad is an exceptional case, because it does not have a university. However, it has but an important research institute (DLO-ID), which is now integrated in the Wageningen University and Research Centre. Groningen has the most startups (twelve) and has developed an active policy in this respect, with the setup of science and business-centre. Leiden, although rather small as a city, has eleven startups within its city limits. Amsterdam, as Leiden concentrating on general biotechnology and medical care, has eight companies. Utrecht, Wageningen and Nijmegen each have seven companies, Delft five and Maastricht (the latter is one of the youngest universities) each have 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.

The general pattern in the Netherlands is more or less diverging from patterns in other European countries. Germany for instance has clearly concentrated its biotech research through its BioRegio programme in some of the Länder. France has also centralised its research efforts. These efforts point at a general national or regional master-plan for the promotion of biotech. However, such a master-plan does not exit in the Netherlands. Each university develops its own strain of research, however, often in close cooperation with other universities or industrial laboratories.

7.5 Division of labour and coordination in biotech research

7.5.1 Introduction

In this sections we will discuss how innovative activities and directions in research have affected the working relations between economical actors in modern biotech. This is a rather tricky undertaking for several reasons. First, modern biotechnology is a container for several directions in research, but the differences between each branch of research are considerable. The dynamism between applications in environmental care or applications in human healthcare is, in fact, hardly comparable. Both streams of research differ in scope, riskiness, regulatory regime, financial investments, partnerships, public appreciation, and research orientation. But even more related sectors, show different dynamism. Take for instance the matter of research partnerships. Hagedoorn has calculated the relative contractual partnering indexes (RCI)[1] for several research intensive sectors. He concluded that the pharmaceutical industry has an above average preference for contractual R&D partnering throughout most of the past decades, whereas the chemicals and food sectors rather have a preference for joint ventures. However, the relative contractual partnering index for these sectors differs considerably.

The RCI for the pharmaceutical industry is 2.12, whereas the score for the chemical sector is 0.27 and 0.29 for the food sector. (Hagedoorn, 2002, pp. 477-492). A second complicating factor is that firms differ in scope, size, history and reach. A large multinational enterprise (LMNE) for instance, with its typical division of labour along several departments and hierarchical systems to coordinate its activities, has clearly different dynamism and characteristics than the small, highly specialised, and highly integrated startup firm. These differences may lead to considerable asymmetry in power relations and in knowledge production, especially in network relations. However, the willingness of actors to participate in networks indicates that the network-partners have at least some mutual interest, strong enough to balance asymmetry between them.

[1] The relative contractual partnering index (RCI) is calculated per sector as the relative distribution of the number of sectoral contractual partnerships (CP_i) and sectoral joint ventures (JV_i) set against the ditribution of all contractual partnerships (TCP) and all joint ventures (TJV).

$$RCI_i = \frac{CP_i / CP_i}{TPC / TJV}$$

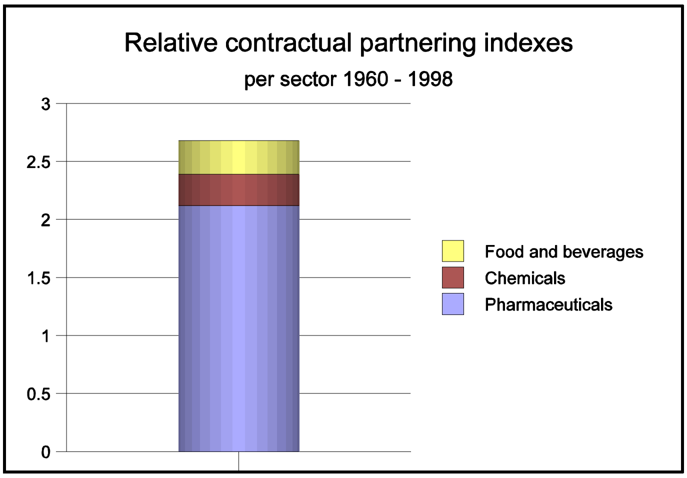


Figure 68 *Relative contractual partnering indexes, per sector 1960 - 1998 for selected technologies*
Hagedoorn, 2002

The rationale is that firms do not innovate in isolation. Instead, they generate their knowledge through interactions with a number of other actors. Even the largest and technologically most self sufficient organisation requires knowledge from beyond its own boundaries. It follows that innovations do not originate only from individuals or individual organisations, but rather from their, often complex pattern of interactions (Schibany and Polt, 2001). This is especially the case in high tech industries. Especially pharmaceutical research-partnerships have increased since the nineteen seventies and currently account for 30% of all research partnerships in high tech industries (Hagedoorn, 2002, p. 483)

Thus, mapping interactions in modern biotechnology is not easy. Knowledge-transfer through co-operation networks can take manifold forms and innovation-related information flows are of a multifarious nature. Archibugi and Michie have argued that such flows take place through market and -non market transactions. A substantial amount of technology and knowledge transfer takes place, because individuals simply learn, imitate, and exchange knowledge while at work. Furthermore, firms use a variety of sources to innovate, thereby using tangible as well as intangible assets. A piece of machinery embodies new technology and the operation of that particular machine demands new skills. Therefore, knowledge is transferred in the acquisition and operation of equipment. The amount of knowledge transferred may even largely resemble the impact of a scientific paper. Both assets, the machine as well as the paper, are important sources of innovation. Furthermore, innovative activities include a variety of actors form the private as well as the public sector. Universities, research institutes and other government agencies play a crucial role in fostering technological advance, as do profit seeking business firms (Archibugi and Michie, 1997).

Innovation is, thus, basically the management of the flow of knowledge from different sources into one project. Different views may generate unexpected ideas. Novel combinations often stimulate researchers and scientists to take a look in each other's kitchen, to see what's cooking there. Understanding the routines, codes and logic of other partners in an innovation project helps to understand one's fads, fancies and blind spots. It is especially in the cooperation of different groups that creativeness comes to the surface. Close cooperation helps to establish a common cognitive frame, overlapping knowledge structures, a common shared language, and a recognition of each other's knowledge domains (Hage and Hollingsworth, 2000). This may be easier said than done, but once a shared framework has been established, its knowledge-base and language allow individuals to exchange and combine aspects of knowledge which are not common among them (Grant, 1996). These horizontal linkages, that fuel the innovation-process from different angles and from different knowledge-bases are not only organised within the company, but also between companies. Companies use markets to get access to valuable knowledge.

The organisation of complex value-adding systems tends to involve markets, hierarchies and networks (Hämäläinen and Schienstock, 2001, p. 25).

Networks can be organised in different ways. We usually refer to networks as an interaction between economic actors, and thus, as an interaction of different companies. But there are also networks-like structures within the hierarchy of companies, for instance, when departments along the idea-innovation chain are mutually involved in research and innovation projects. This is especially the case when there is a considerable overlap between the phases (e.g. Rothwell's model of parallel and integrated model of innovation, 1994, and Imai's modes of innovation, 1985). In these cooperation projects the departments can hold relative equal positions. What binds departments to a project is the search for synergy, which involves elements of trust, reciprocity and obligation, that reach beyond the department's primary task in maximizing profits.

Networks can also exist between departments and other actors, outside the firm. This may be with small firms, that supply the firm with specialised services and products, but also with universities or research institutes. These networks can vary in their degree of formality. An 'old-boys-network', building on shared experience and personal relations, has different characteristics than strategic alliances, joint-ventures, licencing-agreements, or other inter-firm agreements.

7.5.2 Mapping cooperation between economical actors

In this section we will map the relations of the actors in more detail and discuss how they are (mutually) involved in relations with other actors, whether in the form of hierarchies, network-relations or market relations. We will use the layout of the graph opposite to draw the relations between the actors.

The idea-innovation chain

The starting-point in the graph is the idea-innovation chain, with seven innovative domains, ranging from basic research to marketing and sales. Innovation may take place in each of these domains and several actors may be involved. The idea innovation chain is to be seen as the rows in an imaginary matrix.

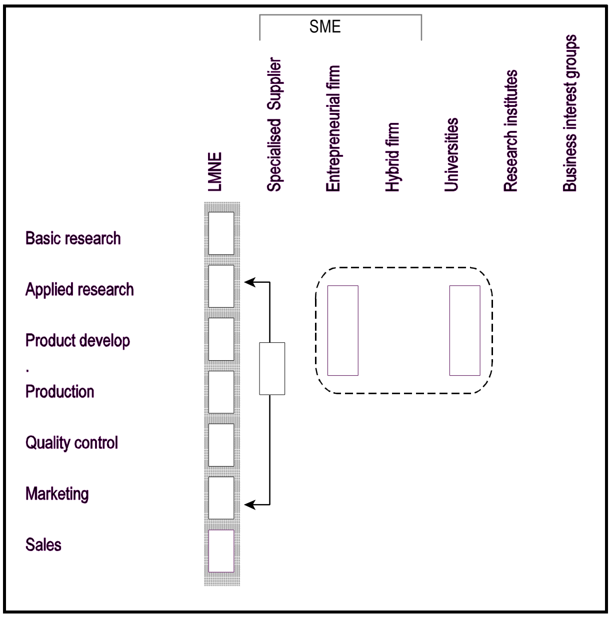


Figure 69 *Mapping market-relations and networks in innovation processes. Arrows indicate market relations and dotted rectangles indicate networks*

The actors are to be seen as the columns in the matrix. First, there is the large, multinational enterprise (LMNE), which is usually organised as vertical integrated hierarchy, with its typical administrative-bureaucratic control structures. The LMNE usually includes all the phases of the idea-innovation chain, from basic research to marketing and sales. The LMNE also includes the complete production chain, from raw material to finished products. The product of the LMNE is usually sold to a final customer.

Next we find three types of small and medium sized enterprises (SME). First there is the specialised supplier of products and services which are used by other actors, somewhere along the idea innovation chain. These firms may for instance, have specialised in a particular field of research, a particular technology, or a particular set of equipment that is valuable for other actors. Second, there is the entrepreneurial firm[2], that aims to develop and commercialise breakthrough technologies (see for instance Ernst & Young's definition of an ELISCO). The typical feature of such a company is that it has been founded by scientists/engineers, that the initial growth of the company is rather based on the provision of venture capital than on revenues and that a high percentage of the employees are working in R&D. Third, there is the hybrid firm, usually a spinoff of universities or research institutes. These firms bear the characteristics of commercial businesses, as well as of knowledge institutes, which gives them a special position in the flow of knowledge. A typical feature of the hybrid firms is that some of their key staff, perhaps even their founders, retain formal appointments in research institutes and universities and, more importantly, have numerous informal networking links that facilitate flows of knowledge to and from the firm. In such cases, the boundaries that distinguish 'the firm' from 'the government-funded research institute' or university are blurred from all but a legal point of view (Fransman, 2001, p. 264; cf. Etzkowitz, 2000, p. 320).

The next two actors are the knowledge institutes. On the one hand we find the universities and graduate schools, and on the other the research institutes, which comprises both private, public and semi-public institutes. The knowledge institutes are increasingly important as economic actors, because much of their work is based on contract-research for companies. Furthermore, the knowledge institutes play an important role in the generation, and the dissemination of knowledge.

A special category is formed by business interest groups. Partly these are intermediary institutions which aim to build bridges between the world of science and industry, or the world of small businesses and finance. Partly they are also to be seen as associations, which aim to promote the sectoral interests. Usually they combine several of these functions.

The relations between the actors in the idea-innovation chain

These actors, that we have depicted in the above, are involved in mutual relations to divide, coordinate and control their actions. The most important mechanisms can be categorized under hierarchic control, market relations or networks. A hierarchy in the graph is indicated by a shaded area. The relations between the actors in a hierarchic system are ruled by a bureaucratic, administrative control-structure, such as to be found in the classical, vertically integrated firms. (The LMNE in the example-graph is indicated as being a hierarchy)

Other relations are organised as market-relations, with one actor supplying the other with a specific service or good (in the example-graph we indicate this with arrows in the fictitious example). There is no other mutual involvement whatsoever, than the transaction of that specific service or product. Finally, we have the network-relations, which are indicated by a dotted rectangle. (the dotted rectangle in the example-graph indicates the fictitious example of a network involving an entrepreneurial firm and a university in the field of applied research and product development).

The procedure

Based on the graph discussed in the above, we will map the relation of the actors in the two sectors. For each actor we will discuss the relations which are characteristic for that specific actor, or the

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[2] The specialised supplier, as well as the entrepreneurial firm has the characteristics of the Independent Dedicated Biotechnology Firm, as we have discussed them in the previous section.

relations for which the actor is the main driving force. In this way we avoid to loose track, especially when actors are involved in different types of relations.

7.5.3 The large multinational enterprise

In modern biotechnology we find the vertically integrated firm in the pharmaceutical industry, the agro-food industry and the chemical industry [3]. These firms can be characterised as hierarchies, even though there is considerable degree of networking within the firm.

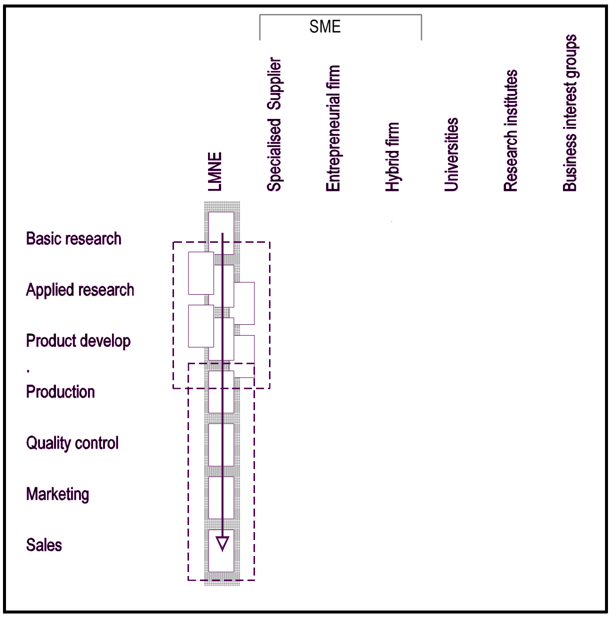

Figure 70 *Cooperation along the idea-innovation chain in large multinational companies*

Usually these firms have a history in classical biotechnology. Modern biotechnology provides these firms with new opportunities to broaden their market and develop new prospects. These, usually well established firms have taken up the challenge of using the new set of biotech tools and have set up special programmes in modern biotech research, next to their regular programmes in classical biotechnology.

Although the characteristics of these new biotech tools differ from the classical tools, the introduction of this new line in research and production has not really affected the setup of the idea-innovation chain. The research and innovation activities are basically organised in a sequential mode, whereby the output of a certain department is the input for the next department in line (this is indicated by the arrow in the graph). Novelty is thus, stepwise guided through the phases of basic research, applied research, product development, quality control, marketing and sales. In modern management approaches, this involves market-relations between the departments.

However, not all the relations can be characterised as internal market-relations, there are certain exceptions, especially in the pharmaceutical industry and the food industry. 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 possibly jeopardise the results of that procedure. In practice, the first three steps, from basic research to product development are often closely interwoven in networklike structures and are characterised by a moving back and forth along

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3 Examples: Unilever, AKZO Nobel, DSM, AVEBE, Nutricia, Campina, Advanta.

each step. The downstream phases however, are meticulous defined by legal admission procedures, which may stretch over several years. For a good result it is important that the departments in the downstream phases of the project coordinate their activities most carefully. These internal, network-like structures are marked as networks.

Similar admission procedures are to be found in the food-industry, although not as detailed and standardised as in the pharmaceutical industry. Once a product is admitted on to the market, it may flare out to a range of products and brands, each with its own dynamism. Managing this process of product variation demands close cooperation between the downstream phases of the idea-innovation chain, and thus it has many of the characteristics of highly-integrated networks.

The main characteristics of the innovation process in large vertically integrated enterprises are determined by a step-wise, linear mode of innovation, however with several network-characteristics. The research departments of large vertically integrated firms increasingly cooperate with each other in networks, especially in the field of pre-competitive research. AVEBE for instance, worked in close cooperation with Mogen and Delft Gist in a research project aiming to fight disease in potatoes.

7.5.4. Service oriented firms

The service-oriented firm in biotech is the provider of a specialist service or products to other actors which are active somewhere along the idea innovation chain [4].
These specialised services or products can be provided to any phase of the idea-innovation chain, but in practice most of these services and products are provided in the field of basic and applied research. This is especially the case when large laboratories have out-sourced specialised research to service-oriented firms, which have the scale, scope and ambition to perform specialised research at a reasonable price. This is for instance, the case in bio-informatics. These companies identify substances, classify them, and put the results in huge databases. This is extremely valuable information for other companies along the idea innovation chain, because scanning substances for their properties and characteristics on one’s own, is far more expensive than consulting a database.

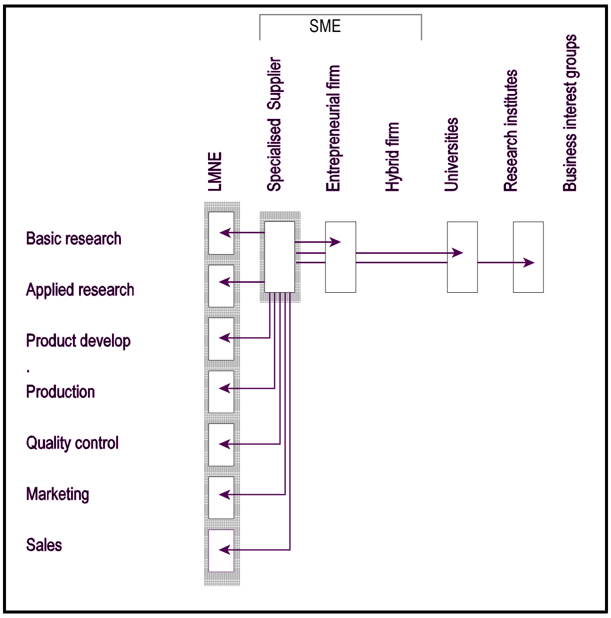

Figure 71 *Cooperation of service oriented firms along the idea-innovation chain*

4 Examples: Cellscreen, Baseclear, Bio-Rad laboratories, Dyax Target Quest, Keygene, Kreatech, etc.

However, the specialised services and products can also be delivered to other phases of the idea-innovation chain. Here we can think of the work of specialised consultants or advice companies, that have developed specialised skills. Often these companies combine expert knowledge with general skills in management or marketing.

Here we can also think of specialised tools, such as diagnostic kits, which can be used in production and quality control. These kits, based on bio-technological agents, are often much more efficient, and often more reliable than the classical kits and procedures. These kits are widely applied, for instance in slaughter-houses, creameries and other firms in the food-industry to detect pollution.

The service-oriented firm in biotech is usually a small firm with a high degree of specialization and integration. However, as a firm matures, it tends to develop like a vertically integrated firm, with a hierarchic division of labour. Thus, in a larger service-oriented firm, one can once more identify the steps of the idea innovation chain.

Important for a service-oriented company is that they upgrade their service constantly to be attractive for their customer, especially in high tech environments. For that purpose the firms communicate with customers and knowledge suppliers to keep on track of dynamism in the sector. If necessary they adjust their service to new demand, and here the firm often cooperates with universities or research institutes. However, the drive to keep the service state of the art is originating from scientific and technological developments in their specific field of expertise, rather than from customer demand. The relations between service oriented firms and their customers are usually regulated by the market. The transfer of knowledge between the service-oriented firm and its customers is usually limited.

7.5.5 Entrepreneurial firms

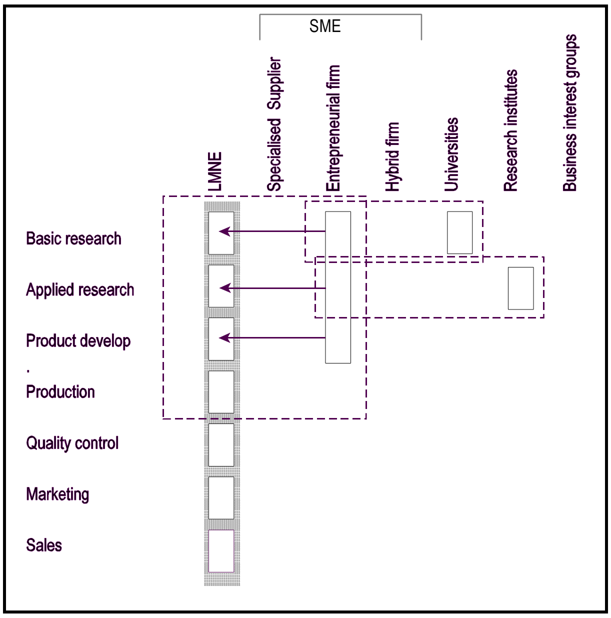

Figure 72 *Entrepreneurial firms along the idea innovation chain*

The entrepreneurial firm has the greatest appeal in life science. 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 often seen as a major indicator. The entrepreneurial life science company is the most appealing in that it uses high-risk strategies, with the prospect of massive gains. The firm is usually extremely research oriented, mainly concentrating on basic research, applied research and product development. The dark side is that success can easily collapse as could be observed in the bankruptcy of the Pharming-group, until recently one of the flag-ships in Dutch biotechnology [5]. In sight of market-introduction of medicine to fight Pompe's disease, the company lost confidence of shareholders and it is most likely that important parts of the company will be sold to one of its former competitors. The Achilles' heel of the entrepreneurial company is its dependency on venture capital or a listing at the stock-market. The entrepreneurial type of firm is initially loss-making, with only few revenues of their own. This is especially the case in the pharmaceutical sector with its time consuming, and money-consuming admission trajectory.

The main asset of the entrepreneurial firm is its knowledge. Its patent portfolio is basically its main asset to generate revenues. Most of the entrepreneurial firms are involved in a complex web of strategic alliances, joint ventures and other organizational agreements.

Most of the entrepreneurial type of firms is to be found in the pharmaceutical industry. 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. The admission procedure is extremely time and money-consuming and it is partly for that reason that the entrepreneurial firm steps into a range of strategic alliances[6], with large, capital-rich companies to finance the whole admission trajectory. Some entrepreneurial companies are -sooner or later- integrated in large companies, which have the funds and skills to bring a product on to the market, such as production facilities, quality control, legal departments, distribution, marketing and sales. However, some larger firms, as well as the small entrepreneurial companies prefer to remain independent. The small firm is thought to have better properties in orientation, flexibility and creativity. Thus, an entrepreneurial firm may develop similar characteristics as the vertically integrated firm.

The entrepreneurial firm is on the one hand involved in strategic alliances, joint ventures and the like, but on the other hand involved in pre-competitive networks with universities or research institutes. Knowledge is its main asset and these contacts with knowledge institutes provide easy access to the source of knowledge. Yet, an entrepreneurial firm is only rarely found in its purest form. Usually these firms are a mixture of an entrepreneurial firm and a service-oriented firm to be able to generate revenues to finance at least a part of their research efforts.

7.5.6 Hybrid firms

The hybrid firm in biotech is usually a spinoff from a university or a research institute. This type of firm has some of the characteristics of a private firm, but the dynamism is based in knowledge institutions. This type of hybrid firm is often 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 (or no longer) fit in the structure and funding systems of knowledge institutes. Some hybrid firms even have emerged reluctantly, for instance as a result of budget-cuts at universities or research

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[5] Other examples: Crucell, Pharming Group, Pepscan in pharmaceuticals, Aventis, Novartis, Syngenta Mogen in Agriculture.

[6] 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 Only recently the Crucell group has been taken over by DSM.

institutes.

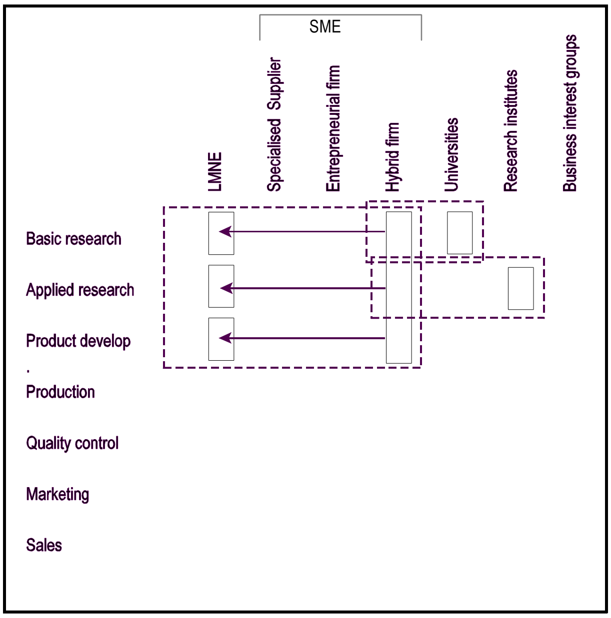

Figure 73 *Hybrid firms along the idea innovation chain*

Hybrid organisations are especially to be found in basic research, but they are also present in the area of applied research and product development. Even though the hybrid firm is profit oriented, it rather has much of the attitude of a knowledge institute. This entails easy access to knowledge networks and easy communication of knowledge. Here the hybrid firm differs from the service oriented firm. Whereas the latter has market-based relations with knowledge institutes, with little dissemination of knowledge, the hybrid firms have network-like relations with the knowledge institutes with frequent interactions, and considerable exchange of knowledge. Hybrid firms are most likely to be found in the science and business-parks, close to the vicinity of universities. Often these firms still cooperate with university research groups as an operational unit and it is no exception when they are housed on campus in the same buildings as their former colleagues. The employees still attend the same meetings and use the same coffee-machine as their university colleagues. This makes relations very informal, which provides an easy flow of knowledge to and from the universities, graduate schools and research institutes. Hybrid-organisations are usually very open, and -still- bear many of the characteristics of university-research groups, where they have evolved from. There are basically two perspectives for a hybrid firm. The first is to exploit the knowledge to the full extend in a service-oriented firm. Indeed, some hybrid organisations have already developed into service oriented companies, especially when they have proven to be able to stand on their own feet. The other is to choose a high-risk strategy and develop into an entrepreneurial firm. However, this is less likely to happen. For that the hybrid organisation seems to lack the real entrepreneurial spirit.

7.5.7 Universities, graduate schools and research institutes

Knowledge institutes like universities and (public or private) research institutes have already been touched in the above, but some relevant aspects of these organisations have not been addressed 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 especially characterised by an open flow of knowledge. The publication of scientific results is a standard for a university's performance. Their education task is only one of the means to transfer knowledge. Scientific papers, publications, demonstrators and prototypes are as important.

In the emerging field of genomics research one can find several forms of cooperation. The core of biomedical genomics research is centred around Leiden University, but there are also important research efforts at the universities of Amsterdam (UvA), Rotterdam (EUR), Nijmegen (KUN). Groningen University has plans for genomics research under construction. Biomedical genomics research has furthermore a strong international orientation.

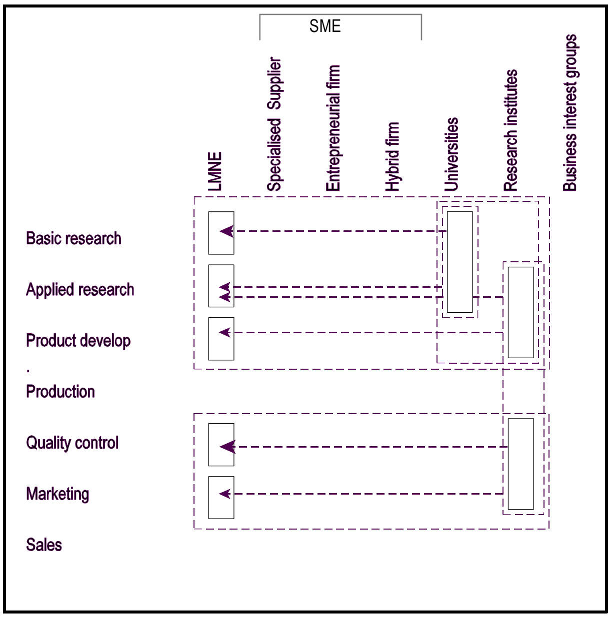

Figure 15 *Universities, graduate schools and research institutes along the idea innovation chain*

The core of food-genomics research is obviously centred at Wageningen University (WUR), but food research also involves the research efforts of TNO-Food (public research institute) and the Dutch Institute for Dairy research NIZO, which is a private funded research institute. NIZO's research is no longer limited to just dairy products, but it has broadened to general foodstuffs. Agro-genomic research is centred around Wageningen (esp. plant research) and Utrecht (animal health). Research in the agro-food sector participates in EU projects, but has basically a national orientation. The cooperation between universities in biotech aims to make an optimal use of complementary knowledge and skills in the multi-disciplinal field of biotech research. Cooperation is also meant to fine-tune plans regarding equipment, investments, IT and laboratory animals. But cooperation is also meant to speak with one voice to the outside world (TNO/Enzing, 2001).

The relations that universities and research institutes have with profit-oriented firms are rather to be characterised as network-like structures than by market-relations. 'Selling knowledge' was until recently considered 'not done' in academic circles. However, the tide is turning. Commercialisation of knowledge is on its way and the hybrid institutions are a good example of that tendency. Universities are increasingly performing third-party contract research. Relations between universities and industries mainly build on network-like structures and that is why the arrows in the graph are also represent as dotted lines.

At universities one can observe two trends. 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.

In biotech we find eight graduate schools that are mainly oriented toward biotech research. Eight graduate schools are partly oriented towards biotechnology, and thirteen research schools have a smaller overlap with biotech-related fields.

The Dutch government has stimulated top-research schools with additional funding. Two of these top programmes have strong relations to biotech research (Materials Science Centre (MSC), and the Netherlands Institute for Catalysis (NIOK)) One of these top-institutes is at the core of biomedical genetics research and combines the work of five research schools (Bijvoet, Biomembranes, Developmental biology, Infection & Immunity, MCG and Oncology).

A special network-like structure exists in the field of quality control. The Dutch institute for dairy research NIZO has evolved from the classical co-operatives. The dairy industry felt the need to set up its own research institute, which could also act like a quality control institute. NIZO was also active in the promotion and marketing of dairy products. Even though it was a public-funded institute, it was highly integrated in the Dutch expert system of the agro food industry and gradually the same attitude as public-funded research institutes. Currently NIZO is broadening its scope to food research and trying to acquire its own market-share in food research. However, it still has its established network-like relations with the dairy industry.

7.5.8 Business interest groups

Strictly taken, the associations do not belong in this listing of economical actors. The associations' first task is to provide and support a business-friendly environment, and therefore the associations should be discussed as one of the institutions. However, another part of the associations' role is to establish concrete networks between the economic actors and that is how we discuss the industrial associations in this context.

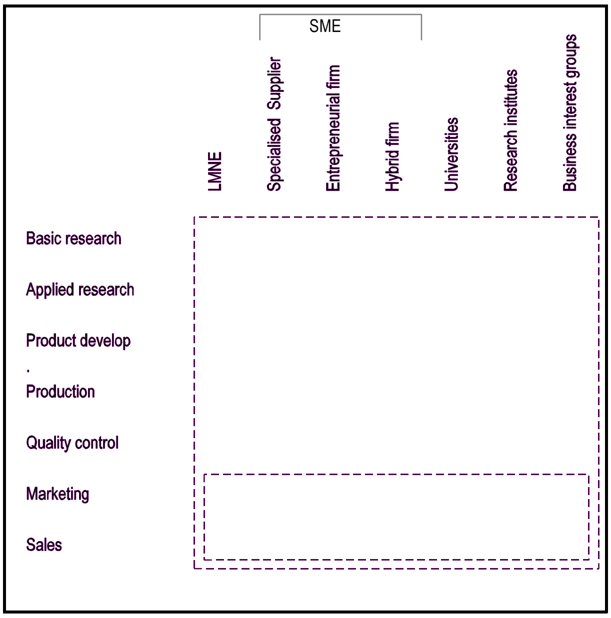

Figure 75 *Associations/business interest groups along the idea innovation chain*

The Netherlands as several associations in biotech, which play an important role in setting the agenda for the (public) debates in biotech, negotiating favourable conditions for biotech companies, and actually playing an important role in the setup of new companies and networks. A joint interest of all the associations is to organise a positive climate for biotech research and the commercialisation of this knowledge. That is expressed in the dotted rectangle that surrounds the fields of marketing and sales.

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. Recently it has changed into the Dutch Biotechnology Association, because the name was too closely linked to agrarian biotech, which has a much lower reception in the public opinion than healthcare applications. Historically Niaba was involved in all fields of biotech application and it 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, it feels that it has a PR-task, because -in her view- the public has been confronted with a lot of nonsense regarding biotechnology. Niaba is also of the opinion that universities and research institutes should have played a more prominent role in informing the public about the benefits and risks of modern biotechnology. Thus, communication, information and public awareness are the cores of Niaba’s activities.

A second field of activity is to promote entrepreneurship in biotechnology. It stimulates scientists to commercialise research findings and guides them to the proper agencies and authorities. In that context Niaba has check-list for the starting biotech entrepreneur, acts as a go-between, and has developed and educational programme, in joint cooperation is the Dutch federation of employers and higher education institutes. 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 generally 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, which 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 in biotech. This leaves the others fields (food, agriculture, environment) much more vulnerable, which in the long run also may backfire on the pharmaceutical 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.)

The universities involved in biotech-research have set up the Association of Biotechnology Centres in the Netherlands (ABON) in the early nineteen nineties. In the organisation the universities of Groningen, Amsterdam, Wageningen, Leiden en Delft cooperate in research programmes. The ABON closely cooperates with Niaba, for instance in the selection of the research programmes. ABON is partly funded by government and partly by the ABON graduate schools.

Associations in biotech closely collaborate and are strongly interwoven. They not only promote the interest of their members, but they also serve as a signalling device to pick up important trends. They help to keep the members informed and discuss new research programmes. Associations are for instance involved as (informal) advisory-group in the setup of the curriculum at several universities.

7.6 Conclusions

How has the biotech sector reacted to the change of the technological paradigm? More specifically, how has the organizational structure of biotech research changed due to the change of the technological paradigm?

The answer is not so unequivocal as it was in the telecom sector. In the latter sector, all was

concentrated around one single technology with only few applications (telephony, telegraphy, telex, broadcasting) and few organisations, whereas biotech is a much broader field, much more fragmented, with each sub-sector having its own dynamism, and with numerous actors. But, more important, the change of the technological paradigm in telecommunication was meant to replace an existing technology, while modern biotechnology was an extension of the biotech toolbox. The modern biotech tools were meant to be used next to classical applications. Modern biotechnology has disclosed the field of genetic engineering, and allowed for new combinations, but it did not make an existing technology obsolete, as digitalisation largely did with analogue technology in telecommunication.
In fact, the research structure in the agriculture, food and chemical cluster was well suited and structured to integrate modern biotech tools in research.

Van der Ploeg (1999) has pointed at the fact that the research structure in agriculture (which has been the first field to embrace modern biotech) was organised as an expert-system, a semi-coherent whole formed by the Ministry of Agriculture, the Wageningen Agricultural University, the DLO research institutes, parts of other Ministries, and parts of provincial authorities which held strong ties with the agricultural sector. This expert-system has been the driving force behind a macro-project that aimed at a restructuring of the agricultural sector according to a one-order-world, a rational model which serves as a signpost for a broad ranges of actors, such as ministries, government agencies and offices, banks, agro-industries, farmers (and his/her family), education, information and research (the OVO triptych). Such a macro-project has served as an encompassing beacon, able to direct and sanction the behaviour of all the actors who are involved in such a project.

Typical for the macro-project in agriculture was its zest for modernity, based on future expectations. This type of system that projects its targets in the future can only function successfully, if there is a high degree of trust among the participants. The reason is that they can no longer make choices in the course of the development-process. Selection in such a future-oriented system is once-only and ex ante. The implication is that competitive alternatives were regarded as inferior and thus neglected and excluded from the system. The determination and the all-encompassing structure of the system have been its strength from the nineteen fifties into the nineteen eighties, but under changing economic circumstances it also turned out to be the system's Achilles' heel (cf. Van der Ploeg, 1999, pp. 3-44).

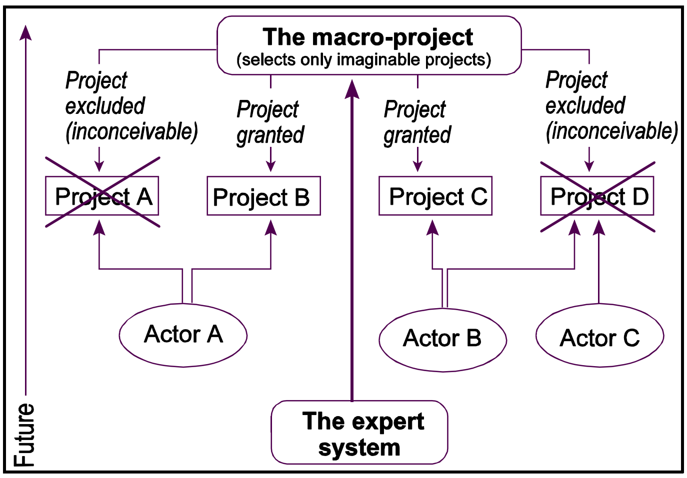

Figure 76 *The macro-project supervising and controlling the actors' behaviours*
Graph based on Van der Ploeg, 1999

In the graph above we have depicted the structure of the macro-project in agriculture. The expert-system has defined the macro-project as an encompassing system that eliminates variety. In its view the future is defined by ever growing outputs, through modernisation, increasing efficiency and a larger scale of production. The future is thus an inevitable, preferable and single possibility and the actors' behaviours should be geared to that single-track development. Innovativeness is much welcomed, as long as it fits the framework of the macro-project. Alternatives are largely excluded, because they are inconceivable for the key-players in the expert system. The perception of the future prospects of modern biotechnology neatly fitted the profile of the macro-project in agriculture. It held the promise of higher yields, improved productivity, improved disease and pest-control, shorter development-trajectories, and better predictable outcomes.

Thus, the change of the technological paradigm did not bring many changes initially. The new technology was welcomed as an extension of already existing lines of research. It broadened the scope of the expert system in agriculture, and most of the activities were integrated in the already existing research structure (the agricultural university and the DLO institutes). The other universities basically followed a similar kind of pattern. Modern-biotechnology held many interesting prospects and it is the task of universities to explore such new fields. The most interesting outcome evoked by the change of the technological paradigm is the development of new, entrepreneurial companies. This is remarkable effect, because it did not fit the general pattern. Innovations of the universities and the research institutes were usually fed back to the sector. The expert-system in agriculture was not only equipped to research promising technologies, it was also well equipped to disseminate new technologies to interested parties. Commercialisation of novelty developed in public research institutes was not-done. The general attitude was that the whole community should benefit.

Then, why did entrepreneurs start new companies? What was the incentive? The Netherlands was among the leading European countries regarding the number of startup companies in biotechnology, thus, the entrepreneurial spirit should be strong! However, that was not always the case. Some companies were founded against all odds. Take for instance the example of a scientist, who worked at a DLO institute, specialised in animal health. This scientist had developed a specific technology to cut up strings of DNA, a technology that could be used in animal healthcare, but also in humane healthcare. The technology provided an excellent starting position for the development of new drugs. However, human healthcare did not fit the profile of the DLO institute, and the scientist had to start his own company to continue his research. Or what about the example of a scientist, who after taking his doctoral degree faced unemployment. The university could not offer him a job and industry was not waiting for his highly specialised skills. He started doing contract research and gradually started his own business. Or the small group of scientists that started a company because the university had to cut budgets. As a result, their line of research would no longer be funded. The only way to survive budget-cuts was to commercialise their findings. Here we have three examples of scientists who started a business rather by need, than by ambition. It goes without saying that the startup-companies that we discussed in the above have very strong links with the institutes and universities from which they have spun off. Many of these companies are still in the hybrid stage, with one leg in business and the other in the institute. It is no exception that the founders still work in the institutes. On the whole, networking is strong in Dutch biotech research and there are numerous links between academia, business and industry. Yet, some relations are basically market-oriented, especially those of companies that perform highly specialised research activities for other research groups. These companies have the size and scope to perform research at competitive prices, but the exchange of knowledge with their customers us less than in network-like relations. However, there are also examples of genuine entrepreneurship, especially in the health-care sector. Some firms have developed most promising lines of research and stepped into strategic alliances with larger pharmaceutical companies.

All in all, the research structure in the agriculture, food and chemical sector was well suited to integrate modern biotech applications, and its new tools were seamlessly integrated as an extension of the toolbox, to be used next to classical biotechnology. This was also the case for the pharmaceutical industry. Modern biotechnology offered a range of new possibilities, especially in the production of basic ingredients for drugs. Insulin for instance, could be produce in a new way and in large quantities, not having the side-effects of the classic drug. The shift of the technological paradigm in biotechnology has indeed opened a wide range of new applications. Experiences so far have been most promising and the knowledge about the genetic structure and its role in the development of disease is about to be uncovered. That is another change of the technological paradigm, moving the attention in human healthcare from cure to prevention. Currently, many university groups are concentrating on this new field.

Chapter 8 The institutional environment

8.1 Introduction

In this chapter we will leave the organizational dimension and concentrate on the institutional environment. The innovative activities of firms and research organisations are dependent on and embedded in a range of institutional arrangements that may hamper, as well as they may facilitate innovative performance. We will especially focus on three institutions that provide the idea-innovation with important resources: finance, skilled labour and regulations. Finance is a very important resource, because it enables firms to invest in more or less risky activities. The labour market and the education system are important because they provide innovation activities with skilled labour and knowledge. Regulations are important, because they demarcate the outer limits of the fields that can be explored.

8.2 Research funding

R&D is usually regarded to be the backbone of the innovation structure. The structure of research activities and the funding of this structure provides direction to the innovation process. The enduring character of this structure opens specific windows of opportunity, but leaves other windows tightly locked. For instance, the macro-project in agriculture and the food industry towards modernisation and increased productivity, has provided specific opportunities. For instance, the Rabo-bank with its strong footing in agriculture, was very much part of that specific expert-system that has boosted Dutch agriculture and the food-industry towards modernisation and increased productivity. It provided the means (money) but it also 'disciplined' the borrower to use the money in the framework of the modernisation-project. Thus, the provision of money was basically a two-sided agreement, with a tradition of risk-sharing. Lending and borrowing is not just a rational game. It was rather a relational game and each loan was part of a long-lasting relationship. As Tylecote has argued (1994), the firm was bound to inform the bank about its position and prospects, whereas the bank was committed to support the firm through bad times, in return for influence over its future directions and operational management. This structure, in which the bank was highly committed towards the modernisation project in agriculture, has opened specific windows of opportunity.

Telecommunication research used to be concentrated in only few companies, which were closely tied to each other in a monopoly-like structure. For research funding the firms could rely on a fixed percentage of the firms' turnover, and these research-funds were provided by the organisations themselves. Banks played no role whatsoever in telecommunication research. Yet, has the change of the technological paradigm changed the structure of research funding? Are banks still the most important funding institutions in current biotech-research? And what about telecommunication? Has privatisation of the monopoly changed the research structure? In this section we will elaborate on these questions. We will start with a general description of the research funding structure in the Netherlands. However, that is only part of the picture. Companies with less than twenty employees are not represented in general statistics and that is pity, because the small entrepreneurial firms in science-driven technologies are especially strong in their innovative performance. That is why we will also devote attention to the funding structure of science-driven startups.

8.2.1 The general research funding structure

The post-war years were characterised by a strong belief in scientific progress as a base for economic prosperity. The support of scientific research was one of the pillars of the Dutch technology policy in the nineteen fifties and sixties. By the end of the 1950 Dutch research expenses amounted 470 million guilders. Government funded 20%, industry 80%. By 1973 the total expenditure on R&D accounted for 3.2 billion guilders, which was 2.4% of the national income. (Schuyt, Taverne, 2000, p.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.

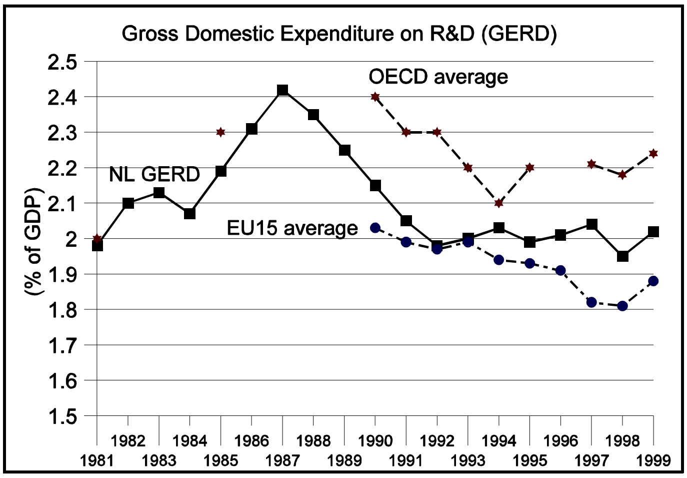

Figure 77 *Gross domestic Expenditure on R&D (1981 - 1999)*
Source: OECD/MERIT

The general level of the Dutch research expenditure in recent years is relatively low, especially compared to the OECD average over the last ten years[1], but still higher than the EU 15 average. The Dutch gross domestic expenditure on R&D (GERD) per capita is slightly over the OECD average and clearly above the EU 15 average. The share of R&D expenditure by private enterprises (55%) is low, compared to the average of OECD countries (69%); Public research funding is accordingly high in relative terms.

Research expenditure in the Netherlands amounted to 15 billion guilders in 1997. Private enterprises take the lion's share with an expenditure of 8,186 billion guilders, which is 55% of all research spending. Universities spend 4,100 billion (27%) annually, while research institutes spend 2,715 billion (18%) in 1997, as is depicted in the graph opposite.

1 Figures of 1996 are not available

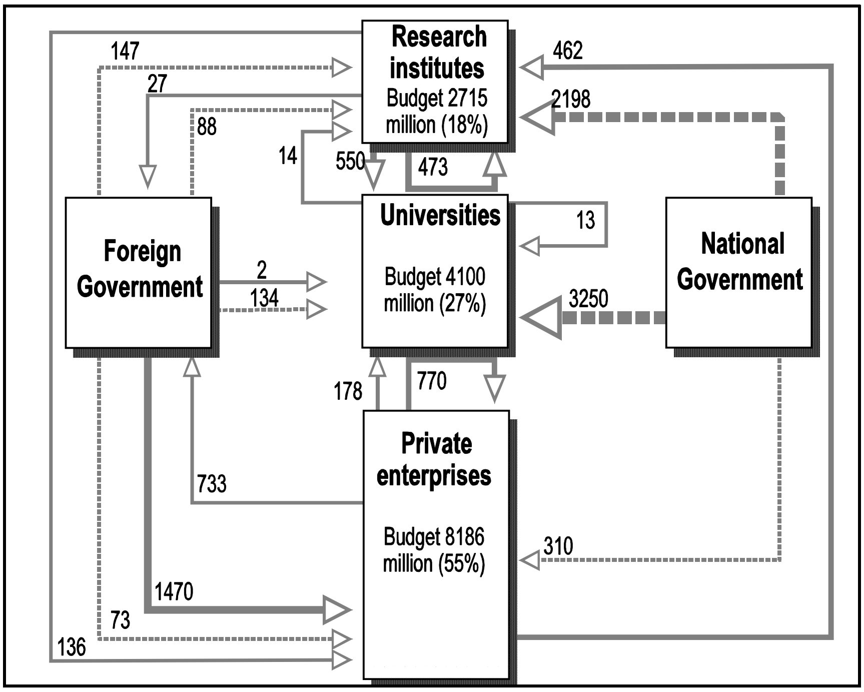

Figure 78 *Research funding in the Netherlands (1997)*
The figures in the rectangles represent the R&D expenditure by the companies', universities' and research institutes' own research staff
The broken lines represent the R&D expenditure of (inter-) national governments
The uninterrupted arrows represent out-sourced R&D expenditure
Source: CBS, 1999

The main source of research funding for industry and the service sector is their own expenditure on R&D. An often used alternative is to out-source research activities to specialised R&D companies, universities or research institutes. This is a strong strategy to acquire technological knowledge and skills through cooperation with other partners. This is an obvious strategy, especially in the transfer of codified knowledge, but close cooperation with partners also offers a range of possibilities for the exchange of tacit knowledge in mutual learning processes. Perhaps more important, companies can spread the risk in cooperation projects. In comparison to other European countries, the Dutch industry and service sector have a preference for cooperation in their own industrial column[2] (CBS, 1999)

Public/private cooperation in the Netherlands is relatively strong. The proportion of company research, out-sourced to universities and research institutes is relatively high in an international comparison. The same is indicated by the relative high degree of scientific co-publications, as well as by the share of company R&D that is funded by foreign countries. It indicates that Dutch research is strongly embedded in global knowledge systems (cf. OC&W/MERIT, 2000).

The main source of research funding for the universities and public research institutes is the national government. Companies do out-source research to the knowledge institutes, but the sum of these expenses is still relatively low in comparison to government expenditure.

[2] It is noticeable that there are hardly any differences between the industry and the service sector in this respect. The sources with an importance for the industry, are also very important for the service sector.

The Dutch research community has strongly participated in the EU framework programmes. Especially the education institutes and the research institutes have a strong performance in the fourth framework programme. In terms of obtained subsidies, the Netherlands had an above-average performance, especially in the fields of biotechnology, biomedical research, agriculture and fisheries, transport, human capital, maritime research, non-nuclear energy and telematics. This is in line with the typical Dutch specialization pattern in agriculture and food-science.

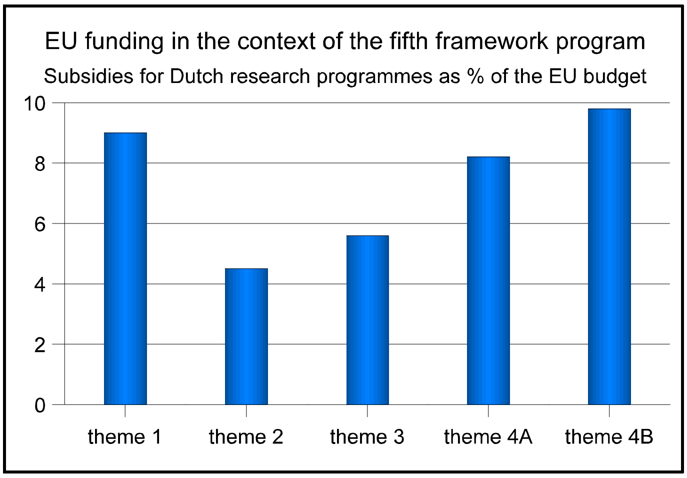

Figure 79 *EU funding in the context of the fifth framework programme*
Theme 1: quality of existence and management of biological resources;
Theme 2: a user-friendly information society;
Theme 3: competitive and durable growth;
Theme 4A: the environment and sustainable development;
Theme 4B: energy
Source: Ministry of Economic Affairs/MERIT, 2000

The Dutch participation in the fifth framework programme has also been very successful. The Netherlands has a particular good participation in the first and fourth themes (theme 1: quality of existence and management of biological resources, theme 4a: environmental care and sustainable development, theme 4b: energy). Both field have managed to bring in more than nine percent of the available budget. However, it has to be noted that the universities have benefited more from these funds than companies, especially in the first theme (cf. OC&W/MERIT, 2000).

By and large we can say that the standard in Dutch research is high, even though the general level of research funding is under decline since the early nineteen nineties. Dutch research expenditure is trailing behind economical development and this is particularly worrisome, because R&D expenditure in reference-countries is gradually increasing. Especially worrisome is that the research-expenditure for universities has hardly shown any significant growth. This is the result of a series of governmental budget-cuts. The combination of budget-cuts, the aging of university staff, the lack of incentives for young researchers and the attraction of the business sector, might hollow out the Dutch scientific performance.

8.2.2 Startup funding

Research is crucial for startup companies in science-based industries. There is often a considerable time lag between a new discovery and its application, which may even stretch into more than ten years. Especially in highly regulated markets, such as the pharmaceutical sector with its highly sophisticated admission procedures, it is not uncommon when the times lag between an invention and the introduction in the market is more than twelve years, while the costs of research, development and admission procedures easily exceed hundreds of millions Euro's. It goes without saying that research funding is an essential prerequisite for a firm to break even. The only reason for a private investor to invest money in startup companies is that they have the perspective of winning back the investment and eventually benefit from massif gains. A pharmaceutical company that is able to bring a real blockbuster to the market can indeed expect massive gains.

Schumpeter has put the entrepreneur at the centre of the innovation process, as being the main driving force behind innovations. A necessary skill for the entrepreneur is that s/he is able to convince banks and other financial institutions to provide her/him credit to finance the innovation (Schumpeter, 1934, p. 69). Crucial in Schumpeter's analysis is the relationship between lender and borrower. The question if credit will be provided does not solely 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 certainly is not the only touchstone for his/her decision whether or not to invest in the project. Credibility, tradition and interpersonal relations are as important elements, especially in credit-based systems with a dominant role for banks in the provision of money. This has been especially relevant in the decentralised 'green' sector (agriculture and food), where banks (especially the Rabo-bank, with its footing in agriculture) and cooperatives have played such a decisive role in the processes of rationalisation of the sector.

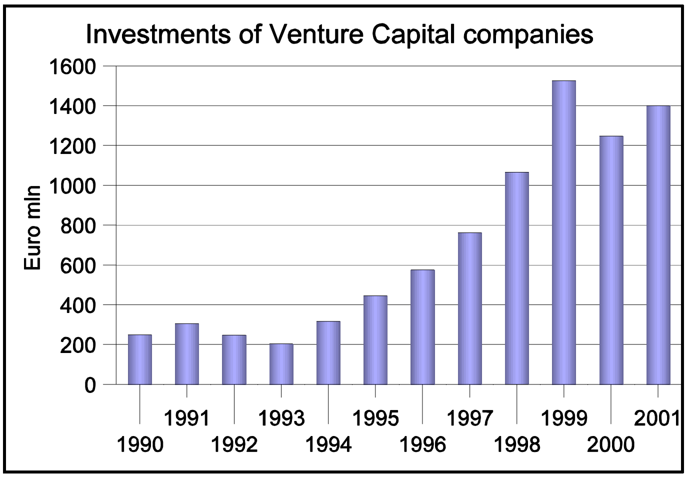

Figure 80 *Total investments of Venture Capital Companies in the Netherlands*
Source: NVP/PriceWaterhouseCoopers, 2001

The Netherlands has historically a hybrid kind of financial system, with important roles for banks (especially in the agro-industrial sector) as well as for the stock market in the industrial sector. Nowadays the importance of the stock-market is still increasing, just like the importance of relative new instruments for the provision of capital, such as seed capital, funds supplied by business angels or venture capital.

The Netherlands has embraced these latter financial instruments relatively early. In 1996 it accounted, together with the UK, France, Germany for more than three-quarters of all European venture capital. The importance of venture capital in the Netherlands has especially started to 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 same case in Europe. For instance, European biotechnology firms received less than 7% of all venture capital investments. However, from 1996 onwards, both number and size of investments in biotech have increased. (National Science Foundation, 1998).

Phases in startup funding
Generally, one can distinguish several phases in the need for capital. The initial phase of a startup company, where the entrepreneur has to research, assess and develop an initial concept is usually funded with *seed-capital.* These funds are often provided from private sources, such as banks or business angels, the latter usually wealthy individuals experienced in both business and finance. After the development of the initial concept, the new-established firm will expand its activities to do product development and initial marketing, a phase which is usually addressed as the *startup* phase. Even in this phase the company has not sold the product commercially. If a startup company has passed the initial stage and has proven to have viable prospects, a third phase breaks in the provision of capital. It will need additional working capital to finance increased production capacity, market or product development. This is usually referred to as the *expansion* phase.

(cf. van Beuzekom/OECD, 2001).

Box 29 *Phases in startup funding*

Currently we find that venture capital is mainly used to provide the funds for sustained growth of startup companies after they have passed the initial phase. Initially it was also used to fund the seed-phase and the startup phase. The funding of the first phase is increasingly left to private investors and venture capital is especially used for the startup and the expansion phase (Ernst & Young, 2002). Usually venture capital funding precedes a valuation at the stock market which is often the proof of economic viability for successful startup companies.

The availability of venture capital in commonly invoked as a fundamental ingredient for the development of a successful science-based company. Venture capital provides first of all a financial basis to prospective academic entrepreneurs, but that is only one side of the medal. The other side is the provision of managerial advice and organizational capabilities, which are inherent to the venture capital funding structure. Venture capitalist provide a coaching structure for entrepreneurs to engage in the right entrepreneurial and business networks, they draw the attention of prospective investors about the properties of a particular new company. Thus, venture capitalists are characterised by a 'hands-on' and 'long-run' approach towards the companies they finance. Their financial support provides a 'mixing ground' for technology, academia and finance and venture capitalists are increasingly part in the networks of conferences, seminars, scientists and publications (cf. Allansdottir, et al., 2002). This is an important asset of venture-capital funding, especially in sectors where knowledge was primarily seen as a good to be disseminated to business and industry, rather than to take initiative in the commercial exploitation of knowledge.

8.2.3 Biotech funding structure

As noted before, research funding in the agricultural sector was mainly credit based with a particular strong role for the Rabobank. Research funding in the food-industry and in the chemical industry was tied closely to this system, but the large industrial conglomerates were well able to finance their research projects from their own budgets. Traditionally, these companies have also participated in many public/private projects. The reason for this specific kind of cooperation is that the agro-food industry has several private research institutes, which are strongly connected to the public research institutes. Furthermore, farmers and breeders most actively participate in decision making in a large part of the public research institutes, especially in practical research (institutes).

The change of the technological paradigm did not bring many changes to the intertwined structure of research funding. The large companies were well able to absorb this new field of technology in the already existing budgets. Furthermore, these firms have participated in several special biotech research projects.

However, science-based startup companies were a relatively new phenomenon, especially, because they came as spin-offs of the universities and research institutes and this was not a very common pattern in the green sector. These new firms had to pass all the stages of seed-funding and venture-funding before they could develop into a regular company. Many of these new startups have balanced for quite some time on the threshold between academia and business, thus profiting from the sheltered environment of the academy, as well as having the ambition to develop into a business. However, that was a pitfall, because a halfhearted attitude is not the best starting point to set up a viable business in biotechnology. This changed when the new financial instruments, such as seed and venture-capital were introduced. Biotech firms increasingly used these instruments and have benefited from the managerial support these instruments offered. Today, biotechnology is a mid-range performer in the Dutch venture capital structure (between 8th and 5th in a ranking of sectors over several years), with shares between 4 and 7% of all venture investments.

Year	Total investments (Euro Mln)	Biotech share	Biotech investments
1998	1066	7%	€ 74,620,000
1999	1526	4%	€ 61,040,000
2000	1248	5.7%	€ 71,136,000
2001	1400	4.92	€ 68,880,000

Table 36 *Venture capital investments in life sciences*
Source: NVP/PriceWaterhouseCoopers, 2000 - 2002

The new systems of startup funding may have found solid ground in the latter years, but it is increasingly difficult to get access to these systems. Our interviewees in biotechnology basically paint two different pictures. The pessimistic picture is that entrepreneurs have increasing difficulty in finding 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). In general there is a tendency that venture capital companies tend to turn away from high risk investments (Enzing, 2000, p. 16). The second, more optimistic picture, portrays the venture capitalist desperately looking for high potential startups. These venture capital companies[3] have good relations with established biotech companies and they use these networks to identify promising ideas and, thus, new businesses opportunities.

None of the stories tells the whole tale, but both tell a part. The early successes of firms like Pharming or Crucell on the Amsterdam stock market has encouraged more entrepreneurs and venture

[3] Among others: Life Science Partners, the Zernike Group, Atlas Venture, Gilde Investment Management, Euroventures Benelux, ABN AMRO Corporate Investments or Tailwind Investments.

capitalists to follow the same path of research funding. This has helped to create a self-sustaining culture of innovativeness and economic strength. However, the partial bankruptcy of the Pharming group and the recent collapse of technology funds has shied off new entrepreneurs.

8.3.4 Telecom research funding

Finance of innovation in the telecommunication sector used to be highly centralised in the large telecommunication companies, which all had allocated a fixed percentage of turnover to R&D. Philips for instance, highly valued R&D as an important element of its corporate identity and reputation. Research at PTT/KPN could also count on a fixed budget, which was basically generated by PTT's own revenues. 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, not only important from a strategic point of view, but also as the bearer of PTT/KPN's scientific reputation. At Lucent and Ericsson we basically find similar high regards towards research and development. The big industrial enterprises of the post-war era used to have close relations with banks, and used to be mainly credit-based companies. PTT was then, still fully depending on state-financing.

One has to bear in mind that innovations in the telecommunication infrastructure were mainly characterised as low-risk, incremental innovations. The general search directions were commonly known and the properties of these directions were broadly defined through standardisation processes. In general, innovations in telecommunications were to be characterised as incremental innovations, bringing novelty within a pre-defined framework of network properties. The technological shift of the technological paradigm from the analogue to digital environment may have been a giant technological leap, but the characteristics, standards and properties of a digitalised system were generally known. Innovation in telecommunication was a carefully negotiated and balanced system of interactions between public operators and the industry in the International Telecommunication Union (cf. Godoe, 2000)

Not only the search-directions for telecommunication research were generally known, so were the expected market-shares. The relations between the public operator and the national industry were tight, with rather fixed market-shares for the main suppliers. This reduced risk for all the companies involved.

Philips retreat from public switching is to be seen as an end of an era. Digitalisation has shifted the core of research activities from technologies for the infrastructure (transmission and switching), to applications, services and software. Multi-media was the key-word in the nineteen nineties and this technological change has brought a range of new high-tech startup firms in the field that is usually addressed as ICTs. The dynamism of these service- and application startups was much higher than in classical telecommunications research. In this booming field of multimedia and ICT companies, with their typical high shares of R&D, venture capital was soon gaining importance.

Year	Total investment (€ Mln)	Communication/ Publishing		ICT		Both sectors	
		%	€ Mln	%	€ Mln	%	€ Mln
1998	1066	6	63.96	9	95.94	15	160.90
1999	1526	7	106.8	21	320.46	28	427.26
2000	1248	15	187.2	16.3	203.34	31.3	390.54
2001	1400	1.03	14.42	13.4	187.6	14.43	202.02

Table 37 *Venture capital investments in ICTs and communication/publishing*
Source: NVP/PriceWaterhouseCoopers, 2001

Communications and publishing and ICTs have attracted the lion's share of the available funds. Participation in ICT companies has fallen in 2000, but still there are 190 companies in 2000 that are funded under the label communication/publishing and ICTs. Venture capital for the communication and publishing sectors have fallen dramatically. In general there is a trend to refrain from technology towards industrial production.

Venture capital companies are especially aiming at expanding companies. That includes high risk, but also high returns. Judging the investments demands thorough knowledge of the sector and that is why the venture capital companies have recruited specialised account-managers to assess the potential of expanding firms. Some venture capital funds create special 'dedicated' funds. These funds are especially useful if their scope and size in large enough. The advantages of scale and scope are best created in an international orientation. Specialization and internationalisation are therefore going hand in hand (NVP, 2000, p.16).

8.3 Education and the supply of skilled labour

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 strong focus on customer demands have changed the competences that workers need to have. This is especially the case in high tech industries, which have underwent rapid technological change. Established technologies have become outdated and new skills have to be acquired for the application of these new technologies. This development is clearly visible in modern biotechnology. For example bio-informatics, which has developed at the interface of ICT's and biotechnology, has not only extended the volume of huge databases, but it also has made these sources of information easier accessible, thus boosting developments in adjacent sectors. Computers can process huge amounts of information. High-powered computers can also perform analysis in a fraction of the time that was needed for the same type of research several years ago. This has clearly influenced the demand for personnel; 'learn-ability' and employability are key in today's human resource management. This demands a willingness in workers for life-long-learning and a high degree of flexibility. Countries which are able to 'supply' skilled workers with these competences, have a competitive advantage over other countries.

In this context it is also important to have the ability to participate in international research projects. The Netherlands has a good position. Not only do researchers participate in many international research projects, but the researchers also have the mentality, multilingualism and adaptability, in short they have the skills to cooperate in international projects. This is an important asset, especially for small countries, because the costs of many research projects stretch widely beyond the reach of a single country

8.3.1 Fear for erosion of the science and technology base

There is a fear among policy makers that the knowledge base in (exact) science and technology is eroding, because young people rather prefer a career in service-oriented sectors, management or economics, than in technology. This poses a serious threat for the innovative capacity in the biotech as well as in the telecom sector. A mutual concern for government and industry is how to persuade young people to start a career in these sectors.

The challenge is how to enhance the attractiveness of careers in science and technology, because the fear for erosion of the science knowledge base is widely felt. 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, the employers' organisations, education institutes and the job-centres 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 total number of students has risen until 1993, but then the numbers have started to fall, basically as a result of demographic developments. This was especially felt in science and technology. The share of university graduates in electronics for instance, has gradually decreased from 2.55% in 1980 to

1.17 % in 1995. The biggest decline in the share of science and technology students 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. In the higher levels of vocational training we find a rather similar pattern. On average, 32% of all male students take courses in science and technology, for female students this is 6%. Also, these percentages are rather stable over time.

From the late nineteen seventies onwards, 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, even the number of informatics-graduates is also under decline.

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%). However, electronics, which still ranked second in 1990, has fallen ever 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. In 1998 it shares a third place 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)

There are two explanations for the decrease of the number and share of students in both electronics and informatics. The first is that the demographic situation has changed. The 'supply' of eighteen to twenty-six year-old's is drying up after the baby boom. The second explanation is that there is a growing interest for disciplines that concentrate on behaviour, economics, management, society and culture. This is nothing new, because there has been a steady incline since the nineteen fifties. These disciplines are specially popular among female students. The influx of female students in these fields also partly explains why the share of students in science and technology has fallen so strongly. Yet, on the whole, the share of students for science and technology is relatively stable over the last decade. On a lower level of aggregation it is however clear to see that the interest for electronics is falling. This is especially felt in the telecommunication sector, because employment in this sector has sharply increased, especially in the broader ICT sector and in the mobile communications sector. The liberalisation of telecommunications has opened new markets, which has resulted in an increasing demand for engineers and technicians. Thus, the heart of the case is not just the decreasing interest in science and technology, but also an increasing demand for high-skilled personnel.

Al in all, discussions about the decline of science and technology, seems to depend on the context for the discussion. If it is true that further economic growth (solely) would solely depend on the availability of new high-quality technology and high educated workers, then there is reason for worry.

This problem is much stronger felt in the telecom sector than in modern biotechnology. 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 indicates that the life-sciences, biology and pharmacology are increasingly popular, while exact sciences like chemistry, mathematics and physics are losing ground. Thus, the education system in the Netherlands is supportive to biotech research in its content as well as in its orientation.

8.3.2 Academic structure tends to separate education from research

Even though the Netherlands has a strong tradition in agriculture and food research, the science position shortly after World War II., was relatively weak. Two important developments have changed the position of Dutch research. 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 full academic career. Students rather opted for a career in business and industry, and broke off their studies before writing a doctoral thesis. Doing justice to this established practice, the university study was split up in two phases. The first four-year phase[4] was meant to make the students familiar with the ins-and outs of a specific discipline. This phase ended with the title doctorandus (drs) for general disciplines, ingenieur (ir) for technical sciences or meester (mr) for juridical sciences[5]. 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.

The rationale of these changes is that education and research have gradually been separated along different lines. Undergraduate students learn the basic principles of scientific research, but are hardly experienced to participate in scientific research in (multi-disciplinary) teams composed by students, PhD-students, post-docs and professors. The ability of students to participate in inter-departmental, inter-disciplinary research-projects and/or joint university-industry projects, is only limited (cf. Allansdottir, et al. 2002, p. 64).

Did the education system hamper or stimulate innovativeness? And did the change of the technological paradigm pose new demands for the education system? To start with this latter question, we believe it did not. The change of technological paradigm largely fitted the profile of new courses in informatics and telematics. Telecommunication is not so much a technology standing on its own, as a particular technological discipline. It is rather a field where different technologies have an overlap. The flexibility in the field was strong enough to buffer new demands. In biotechnology we basically have the same situation. Biotechnology is a toolbox, used by many disciplines, and the new technologies were rather a logical extension of the field of knowledge, than that they were totally new, making old courses obsolete.

Furthermore, the general education system, with its combination of theoretical education and apprenticeship, offers a good enough starting position for an academic career.

In the remainder of this section we will discuss the supply of skilled personnel in the sectors under review.

8.3.3 Supply of skilled personnel in biotechnology

Supply of skilled personnel is not a pinching issue in Dutch biotechnology. Even though there is worry for the future, today companies are still well able to find personnel. One has to keep in mind that not all the workers 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 company's work is basically the application of a single technology in a range of tests where variation is relatively low (such as for instance in service-oriented companies). 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.

8.3.4 Supply of skilled personnel in telecommunication

The supply of personnel has been under pressure in telecommunications, especially in the late nineteen nineties. The classical telecommunication companies used to be a typical example of a machine bureaucracy with a 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 generally regarded to be a linear process. The core of innovation was supposed to come from extended basic research activities. Indeed most telecommunication companies had sophisticated basic research capacities, with AT&T's Bell-Labs as its 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 was 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

4 For medical and several technical sciences the study takes five years.

5 In the context of the Bologna-agreement, these titles will be replaced by the '*Master*' title.

had a large degree of predictability.

Yet, in recent years, changes that have been sparked, not only by technological changes such as digitalisation, and the success of the Internet, multimedia and mobile telecommunication, but also by the opening of new markets in the telecommunication sector. Each mobile provider recruited its own staff, which has led to a shortage of telecommunication engineers. Recruiting personnel had become a pinching matter at the turn of the century. Head-hunters were scanning the universities for talented scientists, offering good contracts, even before graduation. In a 1998 report, PriveWaterhouseCoopers have estimated that between 1999 and 2003 there will be a shortage between 14,600 and 17.200 workers in the ICT sector yearly (PWC. 1998).

The Internet had become an important medium to advertise new jobs. This all has led to an increasing trend towards internationalisation, and currently English had surpassed Dutch on the shop-floor. Companies employ a multitude of nationalities and are increasingly eager to offer talented scientists the opportunity for PhD studies and other training. Yet, all companies have been fishing in the same pond and all were looking for the real big fish. Mobility thus, increased sharply, not only within the firm, but especially between firms. Long term labour-contracts based on loyalty were becoming true exceptions; 'job-hopping' was the word. However, job-mobility is currently under pressure. The Internet/telecommunication-bubble has bursted, the market has collapsed and large telecom-companies have started to hive-off personnel. Today it seems that employment is no longer under pressure and this might probably lead to a more stable labour-market and a lengthening of average labour contracts.

On the one hand firms have had trouble coping with a volatile labour market, because it threatened continuity, but on the other hand they also favoured this development, because there is still so much to learn. Each new researcher brings a load of experience into the company. S/he brings new ideas, solutions and information from other companies. Researchers leaving the firm, in turn, export knowledge to other companies. These exchanges of knowledge are very intensive and provide an easy way to keep in touch with new developments and interesting views. It also helps to bridge gaps in cooperation projects, because the researchers share a general body of highly dynamic knowledge.

8.4 Regulation

Regulations demarcate the playground and directions for research and innovations. On the one hand they put constraints to innovativeness, because they limit the research-area. New combinations might for instance come within reach just behind the limits of the demarcated playground. Yet, regulations prevent researchers from passing critical borders and, thus, put constraints on creativity. On the other hand, regulations support innovativeness, because they help to reduce uncertainty. All that is beyond the borders is simply excluded.

Regulations can be enforced by several bodies. Governments can lay down rules, but so can (inter-) national standardisation bodies. The telecommunication system for instance has a long history of standardisation in the International Telecommunication Union (ITU) which aimed to safeguarding connectivity between different systems and different countries. The implementation of these rules and regulations is usually enforced by governmental bodies or agencies.

From the nature of innovativeness it follows that regulation-systems are usually reactive. An invention or innovation widens the borders of the known world, but the implication they bear can hardly be foreseen. For instance, a telegraph system was already operational in several countries around 1850, but each country had its own characteristics, defined by the broad technological outlines of this new technology. Regulations did not exist whatsoever, which posed the problem of compatibility between system. Countries were used to adapt the idiosyncratic technological standards of the first scientist/entrepreneur to introduce the technology, but there was hardly any harmony between countries. Initially, countries stepped into bilateral agreements and gradually more countries joined that agreement. It took, however, until 1865 before the International Telegraph Union was founded to develop standards for international transmission in telegraphy. From this example we learn that regulations follow innovations, and that they try to avoid problems which are caused by incompatibility of technologies.

Yet, regulations may also have a pro-active character. In biotechnology there is for instance a strain of research to explore the properties of stem-cells. These embryonic cells can be 'harvested' as a by-product of in vitro fertilisation. The promising element is that the development of these cells can be guided towards specific functions, thus their development can be guided towards brain-cells, liver-cells, kidney-cells, etc. This perspective touches upon ethical limits: is it morally acceptable to use embryos for research purposes? In other words, is all that is possible desirable or acceptable? In this case there is only a notion of possible outcomes, but governments have put restrictions already beforehand.

What has, then, been the influence of regulations in the sectors under review? Did they hamper the innovation process, or did they support it? In this section we argue that the regulatory regime in telecommunication has gradually loosened as a result of deregulation and the privatisation of the telecommunication market. For biotechnology we have a different story. Regulation of this field had to be developed in view of the risks that biotechnology could pose, especially to the environment, and to workers in the field. As we will see in this section, the Netherlands has been a frontrunner for European legislation in the biotech field.

8.4.1 The monopoly as a gate-keeper for new technologies

The telecommunication sector used to be a highly regulated sector. PTT had the telecom monopoly and was also in charge with the enforcement of rules and regulations. It allowed only standardised equipment and it was also the sole supplier of equipment and services to the individual subscriber. PTT was also involved in international standardisation. It represented the Ministry in international consultations and was in the position to balance the national system to the basic requirements of the international standards. This stable system began to stagger with the shift of the technological paradigm. Unfamiliar technology, especially computer-oriented technology entered the stage and shook up the blankets. It was generally recognised that fixed networks had been too regulated, stifling innovation and network growth. The Netherlands was the first country on the European continent to follow the regulatory reform process that was set in motion when AT&T in January 1982 agreed to break up the Bell-system monopoly. The basic ingredients for telecom reform were i) private sector participation, ii) market competition and iii) the creation of an independent regulatory body. It also included an opening up of the telecommunication market. Digitalisation of transmission ruled out the Dutch peculiarities in analogue technology and adjusted the system to international technological standards. The new regulatory regime was not so much based on technological issues, it was rather a watchdog to safeguard open market-relations.

8.4.2 New technological approaches demand new regulatory regimes

Regulations in telecommunications have a long history and a solid body of experience to build upon. Regulations in modern biotechnology are as new as the biotech itself. Some areas of research are hardly covered by regulations, while others are regulated by rules, borrowed from adjacent technologies. The admission of new drugs on the market for instance, is based on the rules for classical, chemical drugs. This poses several new problems. Take for instance the matter of tenability of drugs. Chemical drugs have relative stable properties and the effectiveness is stable over a certain period of time. Thus, one can define general rules for effectiveness and tenability. Biotech drugs on the other hand have different characteristics. Biotech drugs are usually composed of living matter and effectiveness may fade over time. Regulations borrowed from adjacent fields may thus be inefficient, but specialised biotech regulations are still under construction.

8.4.3 Regulations in modern biotechnology

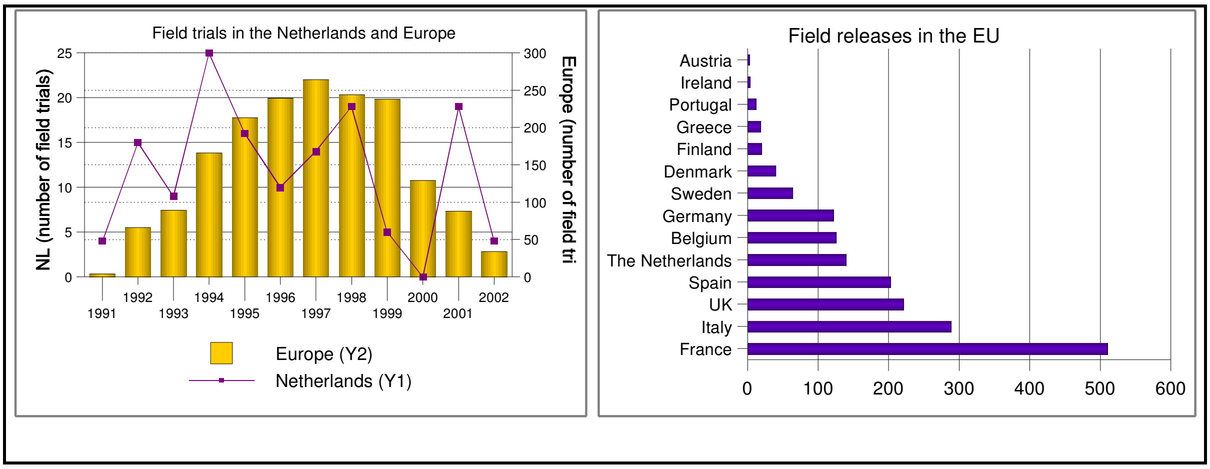

Figure 81 *(left) Field releases in the Netherlands (line) and Europe (bar) 1991 - 2002*

Figure 82 *(right) Ranking of field releases in Europe 1991 - 2002*
Source: European Union/Joint Research Centre

The solid body of regulations, that has marked the telecommunication sector for so many years, is a contrast with the relatively new set of rules and regulations that was developed for modern biotechnology. Initially a set of rules was developed in the perspective of agricultural research projects. Risk was mainly perceived in the light of environmental care. The responsibility for biotech research and the licencing for field trials was under the Ministry of Public Housing, Spacial Planning and the Environment. 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 to describe proper ethical behaviour in healthcare treatment, Another aspect sets out the rules and conditions for scientific research and special treatment (e.g. gene-therapy and xeno-transplants). The reach of this decree is to have an instrument to be able to forbid specific types of treatment. Also in the context of this set of regulations, there is a set of rules regarding welfare and ethics in the treatment of (laboratory) animals.
- Regulation for the evaluation of product-quality and product-safety. In this context there are 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.

8.4.4 New regulatory fields in human and animal healthcare

In recent years the reach of biotechnology has considerably 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. The emphasis in health-care will shift from cure to prevention. Today's treatment systems are still based on a diagnosis of symptoms. Symptoms are the visible indicators of a disease, but the pitfall is that the disease has to develop, before the symptoms show. Tomorrow's system will be based on the screening of the constitution of a person, especially in the light of hereditary diseases. It is expected that large-scale screening programmes will analyse the populations' DNA structure, and will reveal who runs a greater risk in developing a certain kind of disease. If that is the case, the person can start a preventive programme, for instance a diet, to prevent the disease to develop. Future treatment might also 'repair' of the defect DNA structure. The current public debate is focussing on whether or not to set up a screening programme for early detection of diabetes-mellitus.

In the light of this perspective it is evident that rules and regulations concerning healthcare need to be changed. 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 a patient from an insurance policy? And what about the principle of solidarity? Would persons 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 are particular pinching issues for the Ministry of Public Healthcare, Social Welfare and Sports. A project-group has been formed with officers from different departments to study the consequences of the shift in the technological paradigm. Here, 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 regulation itself.

8.4.5 Internationalisation and standardisation

Standardisation is a specific kind of regulation that sets out the technological requirements of a specific technology. Telecommunication and biotechnology are liable to different regimes. The telecommunication sector has been highly standardised from its beginning, thus making international communication possible. There are several standardisation bodies which set out and acknowledge standards between. Initially these standardisation bodies were formed from government representatives. However, with the opening of new markets the regulatory regime in standardisation changed. The trend today is that no longer governments, but industries play the leading part in industrial standardisation of the telecommunication sector.

Modern biotechnology is mainly standardised by notions of 'proper laboratory behaviour' which are inherent to bio-science itself. It provides a rule system of techniques and procedures which is used all over the globe. However, the rule system that was meant to safeguard the environment from possible hazards caused by biotech research has gradually lost its national orientation and is increasingly surpassed by international agreements.

8.4.6 Standardisation in telecommunication

Telecommunication may have been influenced by the general rules and standards of international bodies, such as the ITU, but the characteristics of the telecommunication system were genuinely national. The Dutch telephone-set of the nineteen seventies for instance was still incompatible with that of the adjacent countries. The classical approach towards international standardisation was to agree to such a degree that international cooperation was made possible, but not beyond the point that would restrict a country's elbowroom to serve the interests of its national industry. Even an international standard as ISDN has its French, German, Dutch, ...etc. versions.

The failure of several European technological projects, the debate on the information-sector in the US and the fear for Japanese competition has drawn the attention of the European Community (EC) towards the telecom sector. From the latter half of the nineteen seventies until the mid nineteen eighties it prepared the building-blocks for a harmonised European telecommunication policy, which it had layed down in the Green Book on Telecommunication in 1987. From then on, the EC has implemented a European telecommunication policy step by step. One of the building blocks was the formation of a new European standardisation organisation, because producing standards often took so long that they were outdated once agreement on them could be reached (Schreiber, 1991, p. 99). In 1988 The European Telecommunications Standards Institute ETSI was founded. One of its first successes was to promote the European standard GSM[6]

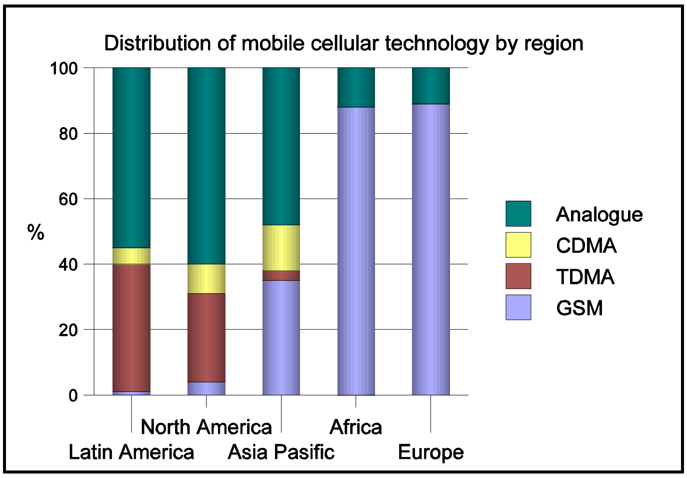

Figure 6 *Distribution of mobile cellular subscribers by region 1998*
Source: ITU, 1999

Even though GSM was developed as a European standard, it has been widely adopted in countries outside Europe, thus fuelling an increasing returns process that contributes to market dominance and industry acknowledgement (Arthur, 1988, 590-607; Bekkers, Duysters and Verspagen, 2002); Bekkers/Liotard, 1999; Bekkers/Smits, 1997). The success of GSM was so overwhelming that the penetration of mobile telecommunication and the diffusion of mobile services is much higher in countries that adopted the GSM standards, than the countries that did not. Even though there is a wide disparity across Europe, with 65% of the Finns using a mobile, compared to 26% of Germans in 1999, the European Union has a world leading position in mobile communication, at small distance followed by Japan, but leaving the US far behind (Booz-Allen & Hamilton, 2000). The penetration of mobile communication in 2001 is such that it has surpassed the number of fixed line subscriptions in all West European countries, while fixed line communications is still higher in the US and Canada (ITU, 2002).

The influence of the European Union on the regulatory structure has largely surpassed the national sphere of influence. Especially since the opening of the European markets in 1992, the EU has taken the

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[6] GSM: **G**lobal **S**ystem for **M**obile Communications.
The EC directive 87/372 has reserved bandwidth in the 900 MHz band according to the binding ITU regulations, thus excluding other possible systems. In addition, though not binding, The EC recommendation 87/371 co-ordinated the introduction of GSM in all Member States (Bekkers/Liotard, 1999)

role of the watchdog to safeguard open competition. National regulation schemes are liable to EU regulations. This has dramatically changed the orientation of the industry and widened its perspective to both European and global markets. The example of mobile communication is exemplary for other fields of technology, whether in switching, transmission or end-user equipment.

8.4.7 International rule systems in modern biotech

> The constructive climate of dialogue and mutual consultation has largely changed since 1998. In that year the Ministry of VROM started to systematically refuse licences for new field trials. In doing so, it neglected its own rules, regarding procedures, scientific consultation and advice, and even neglected juridical judgement. This has damaged the constructive atmosphere that had existed until then, and it had a strong impact for future research. Industry, entrepreneurs, but also venture capitalists were shied-off by the unpredictability and unreliability of the Ministry. Currently there is a fear that agricultural biotech research is increasingly marginalised.

Box 30 *A radical change of attitude in the Ministry of VROM*

Increasing EU interference and jurisdiction has also the case in the biotech sector, however, with a different impact than in the telecommunication sector. The European framework for biotech regulation and legislation was largely based on the architecture of the Dutch regulation system. Since the early nineteen eighties, the Netherlands has been one of the EU member states, leading the development towards a careful legislative system. Bio-technological research, development, testing and production activities have been subject to legislation. The legal framework covers the total field of biotechnology, including approval procedures of novel food products. In the Netherlands, animal biotechnology has been covered as well, including ethical aspects concerning the use of modern techniques. Although legal oversight and control of biotechnology in the Netherlands are tight, government, industry, academia and (critical) interest organisations have constructively aimed to create a workable legislative system for biotechnology. This is the result of intense dialogues in which the mutual goal was to achieve maximum safety for humans, animals and the environment (van der Meer, 1999).

The Netherlands was one of the first countries to set up an effective regulatory framework that widely covered biotech related subjects and provided an assessment framework for the subjects or the products under concern. Some of these regulations were tailored to measure to cover specific subjects in genetical modification technologies, but many technologies in modern biotech were already covered by generic rule-systems. Considerable experience had already been accumulated in fields like the production and testing of drugs and vaccines, workers' safety, food-safety, plant-breeding, etc. At the introduction of new technologies, such as recombinant DNA and the genetic modification of organisms, regulation merely focussed on technology itself. Yet, by the end of the nineteen eighties the focus has shifted towards the regulation of end-products. Traditionally, regulatory oversight in the food sector had focussed on such matters as residues, contaminants, processing aids, packaging materials, labelling, etc. It had focussed on everything, but the main elements of the foodstuffs itself. The plants, animals and other food products had not been subject to regulation. Public and regulatory attention began to focus on food itself as soon as novel technologies and products came available. This has posed a fundamental question. Given the fact that we do not have regulated the bulk of foodstuffs we eat, by what rationale should we start regulating the latest innovations in products or processing modes? Public apprehension about genetically modified foodstuffs and demand for information has led the EC in 1997 to adopt a directive requiring specific labelling of products containing or produced from genetically modified organisms, which are authorised for placement in the market. Food or food ingredients containing, or produced from modified organisms would not require special labelling if found to be equivalent to conventional foods. This has led to considerable dispute within Europe about the precise meaning of equivalence (OECD, 1999a).

Initially, European interference in Dutch biotech legislation has hardly brought any change. The Dutch research structure was already familiar with its national framework that stood at the basis of European legislation, and Dutch biotechnology managed to developed rather prosperously under this framework.

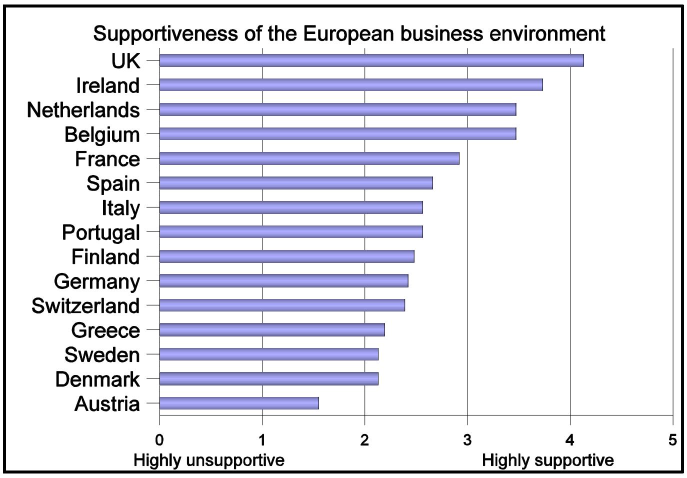

Figure 7 *Supportiveness of the Business Environment for Biotech in European Countries in 1997*
(Mean score, whereby 5 is supportive and 0 is highly unsupportive)
Source: Business decisions/SPRU, 1997

Yet, a turning point was reached in the second half of the nineteen nineties. The public opinion in EU member states like Austria, Luxembourg, France and Italy was strongly opposed against the use of genetically modified foodstuffs and field trials. The EU thereupon declared a moratorium on the introduction of new GMOs. In the slipstream of this moratorium the Dutch government also enforced a much stricter policy in the adjudication of licences for field trials. As a result of these policies there is a tendency to withdraw from modern biotechnology in the agro-food industry. This line of research has plummeted after the Ministry's decision to reject licences, but it is not the only reason. The public opinion in the Netherlands is changing and increasingly critical compared to the in the mid nineteen nineties. However, the public is not equally critical about each application of genetic modification. The strongest rejection in the public concerns the use of animals for cosmetic purposes and for food-purposes. The use of animals for the development of medicine is much more acceptable. The same pattern is also visible in the use of plants, fungus and bacteria, but the general acceptation is much higher than the use of animals.

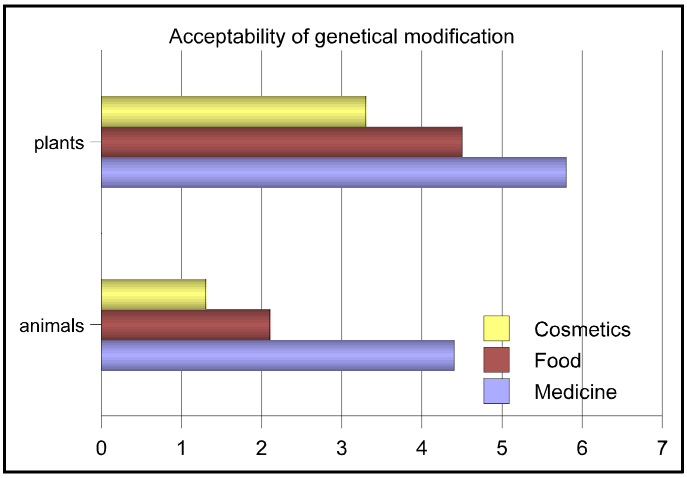

Figure 8 *Acceptation of genetical modification in the Netherlands. Technologies based on the use of animals (lower bars) or plants, fungus and bacteria (upper bars)*
(1: very unacceptable, 7: very acceptable)
Source: SWOKA, 1998

Companies foresee that the tide will be turning in the long run, but it takes too long to wait for the pendulum to swing back. Another reason is that firms have gradually adopted an international orientation. Many small firms have merged with, or been taken over by the large agro industrial companies. Syngenta Mogen is a typical example of a firm that became part of a large research network because of the merger between Novartis and Zeneka in 2000. As a result of this merger the European research-capacity was too big and the smaller laboratories, such as its Leiden laboratory, had to be closed[7]. Furthermore, companies are no longer dependent on a specific country for their field trials. They rather seek the best suitable conditions, and these are difficult to find in the Netherlands. The small-scale characteristics of Dutch agriculture are not the best conditions for biotech research in agriculture. The same is basically true for animal biotechnology. The Pharming group relocated its research in life-stock to Finland, because the risk of cattle diseases was much easier to control in Finland than in the Netherlands. Other research laboratories are closed, because of over-capacity.

8.5 Government policies

The Ministry of Economic Affairs has been responsible for industry- and innovation policy. After the prosperous set-up of a research infrastructure in the nineteen fifties and sixties, it gradually changed its strategy into supporting industries, which were struck by the economical crisis of the nineteen seventies and eighties. However, the results of this strategy were only 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 nineteen eighties 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 nineteen nineties 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

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[7] This pattern can also be observed in telecommunication. After the merger of several telecom companies in Alcatel, the Netherlands lost its research-capacity, because it was too small to be viable in this new constellation.

moment on support of ‘industries-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 core of the Dutch industry-policy is concentrated in five starting points:

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 evaluated the effects that support has brought.

8.5.1 Supporting instruments

Imperfect market conditions have led to the creation of a range of instruments. Some have been 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, however, generally acknowledged that financial investments in the input-side of R&D activities, are not enough. It is only seldom that companies innovate, while just relying on their own strength and qualities in today’s network economy. The ability and will to co-operate in research and development is increasingly critical for companies. The need for cooperation follows from the need for more R&D, as well as the need for specialization and the need for flexibility. The call for more R&D is provoked by shorter product life-cycles, the application of science-driven technologies and the increasing demand for better product qualities. In turn, this has led to more specialization in research and development and thus to the need for more cooperation to coordinate these activities. This is even more the case because shorter life-cycles, rapid technological developments and new information highways (ICTs) demands greater flexibility in research and development (cf. Nooteboom, 1998, pp.20-1)

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. Cooperation also helps to spread risks and costs and helps to limit time to market. Cooperation 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 Europe’s access point on the electronic highway: the Netherlands as the digital delta[8] (Ministry of Economic Affairs, 1999a, 1999b).

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[8] It is worth mentioning that the Ministry of Economic Affairs 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 sufficient 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.

8.9.2 Financial support schemes

Acronym	Aim	Mln gld	%
WBSO	Support R&D	622	66
BTS	Technological cooperation projects	141	15
TOK	Technological development-credit	78	8
BIT	International technology programmes	19	2
KREDO	Credit development electronic services	30	3
EET	Economy, ecology, technology	36	4
SRM	Reference projects environmental technology	3	0.3
SHP	Feasibility-projects SME	6	0.6
SMO	Miritime research	6	0.7

Table 38 *Technology Subsidy-Schemes 1997*
CBS, 1999/Source, Senter

Government has used a range of financial support schemes to promote innovativeness. The table opposite gives an indication of the instruments used in 1997. 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 support scheme 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). The chemical sector benefits most of the technology-subsidies (± 11%), followed by mechanical engineering (± 9.5%), measuring, testing and instruments (± 8.2%). Communication ranks fourth (± 7.5%), food-technology seventh (± 6.8%) and electronics eighth (± 5%). The first ten sectors take 73% of the available budget
(CBS, 1999a, pp.154-162)

8.5.3 Non-financial support schemes

The set of instruments used in T&I-policy is broader than just 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, organising 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 both 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.

8.5.4 ICT support: Twinning

An interesting example of such an initiative in ICT is ‘Twinning’. The concept of Twinning is to promote start-up activity in ICT by making available (venture) capital, housing, organizational support, advice, and providing access to relevant business networks. Young ICT entrepreneurs who have a viable idea and a solid business plan can get support for a given period of time. Support is always a combination of money, facilities and advice. The entrepreneurs can rely on the expertise of people who have acknowledged seniority in business and these 'mentors' also help to open up and exploit networks.

Twinning Business Partners (a selection)	
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

Table 39 *Twinning business partners*

The Ministry of Economic Affairs has strongly supported Twinning, but now, as Twinning 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 services 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.

8.5.5 Biotech support schemes

Government has supported biotech research throughout the past twenty years, in different programmes. The first phase was aiming at the generation of knowledge through a strengthening of the biotech science base. This was especially done in the Innovation Oriented Programme Biotechnology (IOP-b), which started in 1981 and ended around 1987. This programme has proven to be a good instrument, and similar IOP programmes were set up for other economic sectors. As off 1990 the 'grey' biotech sector (fine chemicals and environmental care) have mainly benefited from the IOP programmes. The PBTS programme [9], which started in 1987, was not so much oriented towards the generation of knowledge, but rather to the diffusion of knowledge. Knowledge transfer was the central theme in the

9 Literally translated: Programmed Business-oriented Technology Support Programme.

second phase, which starting in the mid 1980, but has lost ground in the early 1990. From the mid nineteen nineties onwards, emphasis was placed on funding schemes, promoting public private cooperation. Several programmes were implemented, but earlier programmes were often modified in such a way that their targeted character made room for a more generic approach.

In 1998, the Ministry of Economic Affairs commissioned Ernst & Young to do a benchmark-study. A comparison was made with several other countries or biotech regions [10]. 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 Netherlands' 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 most successful regions and countries, the Netherlands did not have 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 (Lucas, 1998). As a reaction the Ministry of Economic Affairs launched its Life Science Startup Action Plan (1999), based on three principles:

1. Emphasis should be placed on the stimulation of new commercial activities, 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 as well as the intermediary;
3. The action plan should involve an integrated approach, in which all phases of commercialisation are supported.

These principles are elaborated in a five-point action plan, which is funded by an annual 20 million guilders. The action plan is published as the Life Science Action Plan and entails:

1. The establishment of a life-science platform, which will be funded with an annual budget of 3 million-guilders. 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 'entrepreneurial 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-plans. This activity will be funded from an annual budget of 5 million guilders.
3. The establishment of incubators to provide the physical environment for life science startups. Incubators provide the specific facilities and supervision, needed to start up a life science business. It is realised that the annual budget of 5 million guilders is relatively low, but the contribution of the Ministry is mainly oriented to get initiatives off the ground, with local initiators. The programme's 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. The realisation of these ambitious plans is laid in the hands of BioPartner, an organisation largely modelled to the Twinning initiative, that we found in telecommunications.

[10] Boston, Cambridge, Berlin Belgium, Sweden, Quebec.

The history of the Integral working document Biotechnology has been quite remarkable. Initially it was agreed that the Minister of VROM would write the first draft. However, when he finally did, the result was so meagre and with so many restrictions that the other ministries took the initiative to draw another draft. The Prime Minister himself had to interfered in this process and the final result is very much a compromise between the cautious approach of the Ministry of VROM on the one hand and the dynamic approach of the other ministries. Representatives of the industry, academia and the biotech associations were very much disappointed, because the paper did not set out a clear direction for the future. It felt like the Ministries of EZ, LNV, VWS and OCW were giving full throttle, while the Ministry of VROM was pulling the brakes.

Box 31 *Different approaches of Ministries regarding biotech research and policy*

Only recently the Ministries of VROM, EZ, LNV, VWS and OCW (2001) have presented the 'Integral Working-Document Biotechnology', in which the Ministries have given an outline for all biotech related policies[11]. In this working-paper it is expected that developments in biotech will equal the booming developments in ICTs of the late nineteen nineties, and it is expected that these technologies will have a strong impact in healthcare, agriculture and the food industry, process industry and the environment. It is realised on the one hand that modern biotechnology may disclose many new scientific possibilities. On the other hand this also entails certain risks and ethical dilemmas. Government has chosen for a responsible system of rules and regulations, which safeguard safety and proper ethical behaviour, but stimulates the Dutch participation in global developments. The before-mentioned Life Science action plan is integrated in this programme.

On the interface 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 Bio-business 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).

Many interviewees have given the Action Plan Life Sciences 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 ambitions are regarded to be 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 rather to concentrate and invest on few potential winners, than to support many ideas with only little money. Many interviewees furthermore wonder if the provision of venture capital is a task for government!?

8.6 Conclusion

[11] The Working Paper has not been discussed yet in Parliament

In this chapter we have given a broad description of the institutional environment in which innovations have taken place. We mainly focussed on the research funding structure, the generation and dissemination of knowledge and skilled labour, and the regulatory system. We furthermore focussed on how government has tried to create favourable conditions for innovation through targeted innovation programmes. That leads us back to our research questions. If a national-sectoral system of innovation exists, what, then, are the typical features regarding the institutional environment? Furthermore, to what extent is the pattern of specialization maintained by institutional arrangements, and how does the institutional environment determine how the sectors have reacted to the change of the technological paradigm?

In general we can say that the conditions for research have been favourable in the postwar years. There was the strong and widely cherished dream that scientific progress could solve societal problems, and the general attitude was truly optimistic. Solutions for pinching matters seemed to be within reach; it was not so much a matter a possibilities, it rather was a matter of time before problems could be solved. The spirit of progress was present in each branch of the industry. However, here we find a marked difference between the telecommunication sector on the one hand, and the agriculture, food and chemistry-cluster on the other. The latter cluster was seen as an important industrial cluster, with growth-strength and dynamism of its own. Here there were new markets to conquer, especially abroad. It was generally felt that the reach of Dutch exports should be extended. The traditional strength in agriculture and foods, but also the Dutch strength in international trading, created a sense and awareness of competition among all players involved. Future profits were within reach, as long as the Dutch performance could meet international competition at least at equal level, but preferably could outperform competitors in productivity and cost control. Innovation was the key to keep a head-start in international markets. This has resulted in a highly dynamic sector with a high growth-potential.

The telecommunication sector was rather seen as a public infrastructure, providing the necessary preconditions for growth in economically strong sectors, such as the industry. That the telecommunication sector could have a growth-potential of its own, was largely neglected. The reason was that all the European telephone operators were organised as a monopoly and that each of them held close ties to their own suppliers, under the shelter of government protection for the inner market. That made it virtually impossible to penetrate new markets in other European countries. This particular structure, in which the (future) market was limited to the inner-Dutch market, made that telecommunication research was not so much oriented towards the creation of new marketable products, but rather to the optimisation of the given network structure. Thus, the drive towards innovation was not as dynamic as in the agriculture, food and chemical cluster.

That the Netherlands, as one of the first European countries made the switch form analogue to digital technology, can only be understood against the background of sharply increasing demand for data-communication in the nineteen seventies. The Dutch business-community, which was so much dependent on international trade, desperately needed reliable connections with international traders and industry, so that the pressure on PTT to invest in digital technology was indeed very strong. This fundamentally changed the position between the telecommunication operator and the telecommunication industry. The operator started to bend over towards its customer, but in doing so, it loosened the ties with the Dutch industry. This was a disappointment for Philips because the life-cycle of its last analogue system, that was only introduced in the mid-nineteen seventies was implicitly shortened by the acceptance of digital technology in the trunk network. Furthermore, Philips was not prepared to the change of the technological paradigm. Although its researchers knew that new technology was under construction in Canada and the USA, it relied on the old paradigm that the large industries could still regulate the spread of technologies. The telecommunication industry had grown lazy under the shelter of the monopolised structure in which operator and industry were closely tied to each other.

By and large we can say that the change of the technological paradigm in the agriculture, food and chemical cluster towards modern applications in biotechnology was welcomed, because it offered a range of future possibilities. Modern biotechnology could be used next to classical applications. It held the promise that breeding and cross-breeding processes could be organised in a better predictable way. Despite the high costs of research, it held very attractive prospects, especially in crops like potatoes and maize. The agriculture, food and chemical cluster was, from the introduction of this technology, very much interested in its prospects and several university groups and industry started several research projects. Later, this materialised in new entrepreneurial companies that sought to exploit the prospects of modern biotechnology.

In telecommunication we found a different situation. The industry was not prepared for the change, because at that time it had trouble to see beyond the direct scope of analogue technology. It had relied too long on analogue equipment, and it was not able to see that digital equipment had far better properties for data transmission than analogue equipment. The industry was not prepared and had not developed the proper skills to meet this new technological demand. Academia, however, realised that new technological domains were about to develop on the interface of telecommunication and information technology. It contracted the two technological fields in the term 'telematics' and took the initiative to found the Telematics Institute. This institute aimed at exploring the new possibilities for academia, business and industry. It still took considerable time before the business community realised the economical prospects of telecommunication and informatics. The liberalisation of the telecommunication market has boosted innovativeness and entrepreneurship, not so much in telecommunication hardware and the infrastructure, but rather in the field of applications for large private and public networks, and in services, especially in mobile telecommunications. The Dutch approach in research was rather to explore future telecommunication services, than telecommunication equipment. Government policies were especially oriented towards the development of a digital gateway, E-commerce and high-speed networks.

The institutional environment has been very supportive for bio-technological. The large agro-industries and the food-industry recognised the prospects of this new approach and were eager to invest in this new technology. The prospects were indeed promising, especially in plant-refinement, which was most relevant for the seed-production industry, the starch-potato industry, the flower industry, the vegetable-industry and several agricultural crops, mainly used to feed life stock. The first biotech applications were oriented toward towards disease-control, pest-control and damage caused by insects. They helped to improve the production process and were aiming at higher yields and cost-effective production methods and the benefits were for the producer. Later applications were rather oriented towards the final user and aimed at improved taste, texture, shape or colour, and still later, the emphasis in research shifted from the agro, food and chemistry cluster to a range of health-care applications.

Government has actively supported biotech research. From the introduction of modern biotech applications, government has also recognised the potential and has made biotechnology a spearhead of economical development. Support was on the one hand built on the extensive expert-system that had come to life in the postwar years, with the Ministry of Agriculture at the heart of this system. On the other hand there were the Ministries of Economical Affairs and the Ministry of public housing, spatial planning and the environment, who joined in that positive attitude. In close collaboration between interest organisations, industry, academia and government a regulatory system was designed that later stood model for European legislation. A system was developed in which each governmental decision was preceded by an advice of a scientific council. The elements of this system fitted like a glove. Also, the generation and dissemination of knowledge were supportive to biotech research. The agricultural university and the DLO-institutes were very much part of the expert-system and well equipped to perform biotech research. Other universities outside the agricultural / food domain were also very interested and developed a range of specialised services. On the interface of business and academia many new companies were formed, that could use the sheltered environment of the universities to make the jump into the world of business. However, many firms have been balancing too long and did not make the final jump towards full economic independence. On the one hand we can say that this is due to a lack of entrepreneurial spirit, or lack of managerial skills. But on the other hand it was a very uncommon thing to do. Disseminating research results to work-floor was regular practice and researchers and scientists working in universities and research institutes were not used to commercialise their findings. Research findings were basically regarded to be a public good. Thus, the strength of the innovation system, with its close working relations between academia and industry, was also its weakness. It was strong in dissemination, but weak in commercialisation.

The provision of venture capital has been a stimulus for biotech entrepreneurship, not only because it provided money for research, but first because it provided managerial coaching. This was also recognised by Niaba, the association of biotech companies. One of its programmes was to organise master-classes to train researchers and scientists how to set up a commercial enterprise. In this programme it closely collaborated with the employers-association and BioPartner, which united several initiatives that were meant to stimulate innovativeness.

However, the tide was turning in 1998. The minister of VROM set in a new policy which was rather based on precaution than on progress. The chairman of COGEM, which is the scientific advisory body in the procedure for field trials put it like this:"The Ministry's current perception of risk is comparable to a ban on emptying a thimble of bathing-water in the ocean, because unforseen contingencies might occur!" The Ministry's new policy has largely undermined the situation of trust that used to be a characteristic in the relations among participants. It shied off entrepreneurs and investors and brought severe damage to the biotech sector. Thus, what used to be a very supportive environment in which the elements were geared to each other, underwent dramatic change, because one of the elements broke the rules that stood at the basis of solid trust-relations. It brought the whole system to staggering, because it no longer had the glue that kept the elements together in a pact of reliability, predictability and trustworthiness. In this perspective of uncertainty companies do no longer count on the Netherlands as a good place for bio-business. AKZO/Nobel has founded its new office in the USA, because the Netherlands cannot provide a reliable regulatory system. Other companies withdraw from the Netherlands for that same reason. In the case that a company has an over-capacity in Europe, it will shut down its Dutch laboratory, because the Netherlands no longer can provide a favourable climate for bio-business. This is worrisome for the short term, but even more for the long term. Government's attitude might usher in an erosion of the knowledge base in biotech.

In telecommunication we found that the Dutch telecommunication industry traditionally has been a follower, rather than a leader. Innovativeness was relatively low and mainly concentrated on the optimisation of the telecommunication network. If there was a specialism, it was rather in transmission than in switching technology. The monopolised structure lacked a sense of innovativeness. Philips developed a SPC switching system, while it was obvious that the US telecommunication companies were strongly involved in the development of digital switches. However, Philips was challenged in its home market by Ericsson and did all to develop an advanced analogue SPC system. The life cycle of this new system was dramatically shortened, because digitalisation was knocking at the operator's door. The operator could not ignore the signals, because the business community needed an alternative for the classical analogue system for data-transmission. Thus, in bending over towards the customer, the operator loosened the ties to the domestic telecommunication industry. In a way Philips was one of the 'victims' of the centralisation process of the telecommunication companies. It could not master the technology, because it lacked the skills to write the software, and had to find a partner with a good track-record in this technology. Nortel was favoured by Philips own telecommunication branch, because it had the technological skills, but also the social skills of how to develop a business in a foreign country. AT&T did not had these skills, but its prestige was valued by Philips' top-management. In the cultural clash that followed, Philips withdrew from telecommunication switching systems and AT&T was the main supplier of the Dutch operator.

The potential of digital equipment was not immediately recognised by the telecommunication industry, not by the operator. The immense possibilities in features, services and applications came floating to the surface while working. A whole new sector emerged, with numerous business opportunities, not only for the large companies with established position in automation, informatics or business-consultancy, but also for small entrepreneurial firms. Especially the Internet gave a twist to these developments and many new companies stepped in this new market. From that moment on we find an excellent convergence of technology, regulatory systems and business opportunities. Digitalisation may have created a new platform for a range of new telecom services, it was regulatory reform that allowed entrepreneurs to step in this new line of business. Initially there was the initiative of government to stimulate competition. In her view a second operator would compete with the old monopoly, in the expectation that this would lower prices for the final customers. However, the second operator demanded monopoly right regarding the exploitation of its telecommunication services and the initiative failed. The flaw of this attempt competition was that is was too much developed within the contexts of the classical, monopolised telecommunication regime. The opening of market for telecommunication network services, the Internet and mobile telecommunication have boosted innovativeness and entrepreneurship in telecommunication. Developments were so fast and success-stories were so appealing that a shortage of telecommunication-technicians and engineers was biting the innovative performance. Venture capitalist were most willing to invest in this new economy. However, the telecommunication-bubble has bursted and what is left is a regrouping of companies, and only the strongest survived. Today we find an ample labour-market and the sky-rocketing prospects of E-business have waned. The large telecommunication companies have hived off personnel. KPN has hived of its total research department to TNO and is now concentrating on the promotion of new services.

The turmoil of the telecommunication market has gone, the high-pitched telecom dreams have evaporated and what is left is a relatively small research sector for telecom applications.

Chapter 9 A comparison of sectors

> *The old man Matzerath, who enjoyed designing encompassing systems of multi-medial cooperation on large blackboards, said:*
> *"Mark my words, tomorrow we will create a reality in which, by the use of multi-media, the future will be freed of all that is hazy and fortuitous; whatever the future, she can be produced beforehand "*
>
> *Günter Grass in 'Die Rättin' 1986*

9.1 A retrospective

Innovation is a strange phenomenon, hard to 'catch' in formal theories. For quite some time it was thought that innovations occurred as the result of determined entrepreneurs who, although not able to foresee the future, were willing to face all the hazards and difficulties of innovation, as an act of the will. In this context Schumpeter, in his initial work (1912), spoke of the heroic entrepreneur. Later he weakened his statement because he recognised that the large industrial companies had institutionalised innovative activities in R&D departments (Schumpeter, 1939). But did that sufficiently explain the innovative performance? Is innovation just a matter of technology, or are there also other factors that influence a firm and a nation's innovative performance? Van Waarden has argued that the structured interplay of institutions and organisations has an increasing significance in explaining differences between countries (van Waarden 1998). The interplay of actors along the idea-innovation chain, the degree to which economical sectors have access to finance and knowledge, the flows of knowledge between academia and industry, and the role of the regulatory structure, also determine the innovative performance of countries and economical sectors.

This is most explicitly captured in the concept of national systems of innovation. Lundvall (1992) has recognised that nation states differ in the structure of production systems and in their institutional environment, such as its historical experience, language and culture. In his pioneering research he proposed to concentrate on the internal organisation of the firm, the inter-firm relationships, the institutional setup of the financial sector, the role of the public sector and variables as R&D intensity and R&D organisation. The national system of innovation-approach holds the promise that it can distinguish the innovation system in one country from a similar kind of system in another country. The pattern of industrialisation and the notions of path dependence have further strengthened the belief that nations matter in the system of innovation, because actors relate to one-another as elements of a collective system of knowledge creation and use. One has to keep in mind that the structure of a system is largely the result of past experience. History matters in the analysis of innovation, because some small events may be reinforced and become crucially important through positive feedbacks, thus establishing path-dependent trajectories (Arthur, 1994; Pierson, 2000).

A shortcoming of the national system of innovation literature is, however, that it easily overlooks significant differences that may exist between economic sectors. Nelson, in his comparative analysis (1993), has argued that the national systems of innovations concept suggests more uniformity and connectedness within a nation than actually is the case. What has been defined as national innovation systems, tends to be sectoral specific. Distinct characteristics pervade the firms in the sector, the education system, the regulatory system and government policies, all of which have been shaped by shared historical experience and culture. However, each sector has its own history, its own culture and its own institutions. We do agree with Nelson that the factors that make for commonality within a country, largely define the factors that make for commonality across sectors, but disagree if the consequence of that statement would imply that one can compare countries on whatever sub-sector. Each economical sub-sector does bear the general hallmark of the national system, but the reverse is not necessarily true. The dynamism of the automobile industry is not necessarily the same as those of the pharmaceutical industry, the textile industry or the chemical industry, and an analysis based on a comparison of randomly chosen sub-sectors might easily lead to wrong conclusions. The interplay between actors in the organizational structure and institutional environment, and the way in which these interactions are influenced, or even shaped by the institutional environment, may differ significantly between sub-sectors. Therefore, we believe that the power of comparison will significantly improve, when it involves the same economic sub- sectors in the analysis.

Do these notions, then, make the national system of innovation concept obsolete? We believe not. The conceptual framework of the national system of innovation approach has not lost an inch of its validity, as long as it limits itself to the comparison of comparable economic sectors in different countries. That is why we propose to extend the national system of innovation analysis with a national-sectoral perspective. Our approach is first and foremost to be seen as an addition to the national system of innovation approach.

To substantiate our position we have studied two sectors in the Dutch economy, which have apparently several characteristics in common. Both sectors are built around science-based technologies. Change in the sector is predominantly the result of technical change induced by (the cooperation in) research efforts in academia and industry. Furthermore, the economic potential of the two sectors is strong, which was reason for the ministry of Economic Affairs to designate both sectors as spearheads of economic development. Finally, both sectors have undergone a significant change in the technological paradigm in recent decades.

However, there are also important differences. The telecommunication industry is predominantly an ‘assembly’ industry, that composes a final product from a range of different parts. The idea-innovation chain of each singular part may be located in one region, but parts of the chain may also be dispersed around the globe. Moreover, its products are part of a ‘large technological system’, which has far reaching implications, for standardisation, mutual adjustment, differentiation and cooperation. The industry in the agriculture, food and chemistry cluster is a ‘process’ industry, that basically alters the characteristics of raw material into semi-manufactured or final products. It is rather a ‘stand-alone’ type of industry, with fewer possibilities to allocate elements of the idea-innovation chain elsewhere, and this has implications for the organisation of the activities along the idea-innovation chain.

We argue that the differences between the two sectors are so numerous that the peculiarities of the innovation systems of the two sectors would not be fully captured in a purely national system of innovation approach. We argue that the differences can only be revealed in a national-sectoral system of innovation approach.

9.2 The peculiarities of sectors

The two sectors under review are the telecommunication sector and the biotech sector.

The history of the telecommunication sector is relatively easy to trace. It started with the simple technological structure of the telegraph network and gradually evolved into the telecommunication system as we know it today. In this study we have concentrated on point-to-point connections, thus excluding point-to-multi-point connections, as to be found in broadcasting. The telecommunication system developed until the nineteen eighties as an electro-mechanical system, based on analogue technology. The analogue system was suited for voice communication, but had trouble in transmitting the binary structure of data-communications. Digitalisation of the telecommunication signals opened a range of new possibilities and from the nineteen eighties onwards new digitalised systems were introduced to replace the old analogue systems. On this new technological platform a range of new products and services have been created. These new services, especially the Internet and mobile communication, have spread quickly. This is on the one hand due to the introduction of optical fibres in the networks. These modern cables have the advantage of low energy-consumption, high speed and high capacity transmission of a very stable signal, virtually without fading over distance. Optical fibres were especially suited for high-capacity transmission such as in data, graphics and video. It was on the other hand due to an ongoing process of miniaturisation. The size and weight of a modern cell-phone are only fractions of the first models. The change of the technological paradigm, and in its wake the liberalisation of the telecom market, broke up the stable monopolised structures in telecommunication, offering a multitude of new commercial opportunities.

A similar drastic change has taken place in biotechnology, but its roots are a bit harder to trace. The principles of biotechnology have been known from ancient times. Malting, fermentation, the use of yeast in bread and beer were already practised in ancient Mesopotamia and Egypt. Farmers have always tried to combine the best properties of animals and plants, even though the underlying principles were only partly known. The discovery of the DNA structure in 1953 ushered in a new era in biotechnology, especially when scientists in the nineteen seventies managed to take a string of DNA from one organism to insert it into another, non-related species. This was only the prelude to modern biotechnology and today we find many applications in agriculture, food, human and animal healthcare, chemistry and environmental care. Our historical analysis has mainly concentrated on the agriculture, food and chemistry cluster as the founding technologies for modern biotech.

In chapter two of this study we introduced a table to summarise the main characteristics of the two sectors. In chapter four we discussed early developments in the two sectors and at the end of that chapter we could fill out the first two columns of that table. The first to depict the situation around 1910, and the second for the situation around 1940, at the outbreak of World War II. In chapter five we focussed on the post-war era and at the end of that chapter we added the third column for each sector, describing the situation around 1970 at the advent of the paradigm change. In chapters six and seven we analysed the organizational architecture of the idea-innovation chain in the two sectors, especially concentrating on how the architecture has changed under the influence of the paradigm change of the nineteen seventies and eighties. In chapter eight we paid attention to the institutional environment during the latter period. Now, in chapter nine, we can finally complete our table by adding the last column in which we depict the situation around 2000.

A_1 *What are the* ***typical features*** *of the national-sectoral system of innovation in Dutch telecommunication and biotechnology, regarding:*
- *The technology involved;*
- *The organizational architecture of the idea-innovation chain;*
- *The institutional environment;*
- *The sectoral patterns of specialization?*

A_2 *Is there any* ***systematic coherence*** *between the characteristics of the system?*

A_3 *To what extent is the* ***pattern of specialization maintained*** *by the organizational and institutional elements of the national-sectoral system of innovation?*

A_4 *How have the* ***sectors reacted to radical change****, especially in their future specialization pattern, the organization of the idea-innovation chain and the institutional environment?*

A_5 *Do national-sectoral systems* ***exist*** *and* ***do they matter****?*

Box 36 *Research questions revisited*

We will discuss the table in detail in the sections to come and in doing so we will answer the research questions that we posed in the beginning of this study. We will follow the main-subjects as we depicted them in the first research questions: the technological characteristics, the organizational architecture of the idea-innovation chain, the institutional environment and sectoral patterns of specialization.

9.2.1 Technological characteristics

In previous chapters we have classified innovations to the degree that there are incremental, artisanal, progressive or radical. At the one end of the spectrum we find small, incremental improvements and modifications to existing technologies within a known technological framework. At the other end we find radical new products, technologies and methods. Nortel and AT&T's innovations in digital technology were indeed radical innovations, but the introduction of that technology in the Dutch telecommunication network was rather a progressive innovation, because it entailed largely modifications of existing products, systems and technologies. Progressive innovations imply that the same things are done (transmission and switching of telecom signals), but in a different way (digital instead of analogue), but better, more precise, more reliable and more cost-efficient. Digital technology was a foreign technology for the Netherlands, invented and developed abroad.

	Telecommunication				Agriculture/food & chemistry cluster			
	1910	**1940**	**1970**	**2000**	**1910**	**1940**	**1970**	**2000**
Type of innovations	*incremental*	*incremental*	*incremental*	*incremental artisanal*	*incremental artisanal progressive*	*incremental artisanal progressive*	*incremental artisanal progressive*	*incremental artisanal progressive*
Scope	*local*	*national*	*national*	*global*	*regional (inter-) national*	*(inter-) national*	*inter-national*	*inter- national*
Leader or follower	*follower*	*follower*	*follower*	*follower*	*leader*	*leader*	*leader*	*leader*

Table 38 *Technological characteristics in two sectors (1910 - 2000)*

If we characterise the role of genuine Dutch telecommunication research, we find that most of its innovations had an incremental character. They include design, re-design and adjustment of existing concepts and products, variations on and improvements of services and operating procedures. There are, however, few exceptions of innovations with a more progressive character. For instance, the development of long distance transmission equipment in the nineteen twenties, in which Dutch engineers took a radically different approach by building on the properties of long-wave transmission. Here they clearly stepped beyond the borders of known and generally accepted concepts and they were true pioneers in this field. More examples are to be found in transmission technology. The early telecommunication network was built with air-lines, which was a most vulnerable system. PTT decided in the nineteen twenties to replace the air-line network by a system of ground-cables. Experiments had turned out that ground cables had better properties, because they offered more capacity and more reliability. The introduction of optical fibres in the mid nineteen eighties created the conditions for another progressive innovation. This technology was designed to meet future demand, and to tailor networks flexibly to the changing need for telecommunication networks and services. Instead of burrowing cables directly into public soil, a large set of empty plastic tubes were burrowed to form a basic network-architecture, allowing for several telecommunication network designs. Optical fibres are later inserted into this network by air-pressure. These optical networks can easily be cut to size and need of individual subscribers, without any digging in public soil. This technology is developed by PTT/KPN research, but later hived off to industry. These examples may have a strong appeal, but they are rather the exceptions than the rule. By and large we can say that most of the innovations in Dutch telecommunication research had an incremental character. The change of the technological paradigm and the liberalisation of the telecommunication market have, however, created a multitude of new opportunities. Entrepreneurial ICT companies are active on the borderline between information, communication and telecommunication technology to develop a range of new products and services. These services are tailored to size and need of the customer. The success of these new applications depends on the one hand on the design capabilities for new services, but on the other hand on the capabilities to implement these new services at the subscribers' organisation. Here it comes to quality to understand the complex interplay between technology and human behaviour, which tends to artisanal approaches in innovation.

The agriculture, food and chemistry cluster has been highly innovative throughout the years. The use of chemical manure for instance was a progressive innovation that boosted productivity in agriculture, and allowed for a range of incremental innovations to harvest the full potential of that innovation. In its slipstream it also created a range of new opportunities for the food and chemical industry. Dutch agriculture has traditionally been a sector where farmers and breeders have sought for the best conditions to exploit their business. On the one hand they rely on the codified knowledge as it is taught in schools, seminars and courses, but on the other they rely on the tacit knowledge of tradition and true craftsmanship. Many innovations in the agriculture, food and chemistry-cluster were incremental innovations. These innovations often induced changes in the same or adjacent fields, mostly with incremental results, but sometimes leading to progressive innovations. Dutch floriculture for instance grew big on the 'geest', the typical sandy soils between the dunes and the polders. However, the floriculture industry had to look for alternative grounds when production exceeded the available surface of the 'geest'. Today, flower-bulbs are grown on nets, even on the heavy clay of the polders, and the results of these experiments are fed back to the industry on the original grounds, and the innovation is currently used in different types of plants and crops, and on a variety of soils.

The new instruments of the modern biotech toolbox basically fit this pattern. They are to be seen as progressive innovations, especially in healthcare and chemistry. The promises of genetic engineering are especially high in modern healthcare and it is to be expected that radical breakthroughs will be achieved in the years to come, especially in the treatment of a range of life-threatening diseases. For now, the character of innovations in modern biotechnology mainly has a progressive character. Doing the same, but in a different way. Insulin for instance is no longer harvested from the pancreas of animals, but synthesised from biological processes. The purity of the ingredients of antibiotics has increased by the use of genetical modified bacteria. The extremely polluting chemical dying of blue-jeans is replaced by a much milder biotech process. Washing detergents are currently based on the activity of modified enzymes, rather than on phosphates. However, there are also radical innovations, especially in environmental care. The cleansing of polluted soils was extremely expensive, because the soils had to be transported to be treated in large cleansing plants. Today we find several in-situ methods, in which genetically modified bacteria are used as active agents. One of the new products is a 'biological fence'. This fence of biological agents is burrowed around polluted areas to prevent pollution to spread.

The scope of innovations in Dutch telecommunication research was traditionally oriented towards improvement of the telecommunication system within the limits of national standards. Only academic research had a more generic, outer-oriented orientation, yet its focus was mainly on relatively small technological elements of the telecommunication system, such as propagation, or the characteristics of different wavelengths. The fact that research was bound to national borders is not surprising. Each country had its own technological characteristics and this was also the case for the Netherlands. This explains why a Dutch telephone-set did not work in foreign countries. It was designed to meet the Dutch standards and in fact these differed quite a bit from designs abroad. The change of the technological paradigm and the liberalisation of the telecommunication market put an end to this national perspective. The telecommunication market was opened and so was the perspective for innovation.

The scope of research in the agriculture, food and chemistry cluster was closely connected to the Dutch export-orientation. Research was on the one hand used to develop products for the export market, but they were on the other hand used to monitor product-quality for the export. Research institutes thus played an important role in the regulation of the food-sector. Take for instance the production of cheese at the beginning of the twentieth century.

Dutch dairy-factories produced large amounts of cheese for the British market. However, there were no product standards whatsoever and several dairy-factories found it profitable to skim off the cream from the milk and to use the low-fat rest-product for the production of cheese. It is obvious that this resulted in a much poorer cheese quality, less taste and shortened storage life. This case was brought to court in 1902 and the verdict was that cheese should hold a certain percentage of fat, and that the percentage should be visibly stamped on the cheese. The only way to regulate product quality was to involve independent research stations in quality-control. Thus, the private research institutes played a double role, on the one hand they developed new products and on the other hand they monitored product quality for export.

The scope of Dutch agricultural research was on the one hand bound to the variety of local and regional agricultural production systems. The Dutch specialised in the breeding of high-quality life stock, the production of seeds, floriculture and horticulture. Independent Dutch seed-companies ranked among the top companies world-wide in the mid-nineteen nineties. A wave of mergers washed over the large agro-industrial companies and many of these firms became parts of large agro-industrial conglomerates. But there was still another reason for the Dutch international orientation. The Netherlands, had extensive colonies in the tropics at the beginning of twentieth century, and had a specialization in tropical agriculture. The end of the colonial era did not stop this specialization pattern and the Wageningen University is still strong today in developmental agriculture. The general scope of Dutch agriculture research was to support its broad production systems, whether, national or international.

In comparison to the innovative performance of other countries, we found a distinctly different profile between the two sectors. The Dutch telecommunication sector is basically a technology follower. This was caused by its initial purchase-policy, in which telecommunication equipment was acquired from abroad, but still, when a genuine Dutch telecommunication industry started, it was largely based on foreign designs (Ericsson and WEC), or foreign licences (Siemens). Even the modifications in Philips switching equipment, were largely based on existing technological concepts.

In the agriculture, food and chemistry cluster we find a different pattern. Historically the Netherlands had a leading role in agricultural research and was very eager to stay on top of technology. That is why it fits the profile of a leader in agricultural research.

9.2.2 The organizational structure

Our understanding of the idea-innovation chain is largely based on the phases, which an idea has to pass, before it is finally on the shelf as a marketed product. In classical models, the start of a new product is seen as the result of scientific efforts in basic research, and from that point the product has to pass through the stages of applied research, product development, manufacturing, quality control, marketing and sales, before it is available for the customer. The logic of this sequence makes sense, but in practice we find many departures from this linear rule of events. Rothwell (1994) found that the linear models were actually a good representation for innovation process shortly after World War II, but he saw new and more complex models emerging through the course of time. Science was no longer the only source of innovation. The market increasingly expressed its own demands and created a multitude of incentives for innovations. Furthermore, the phases of the innovation process were no longer neatly separated. There was an increasing overlap between the phases, especially in the parallel and integrated models of the Japanese assembly industry. Here we find functional departments, simultaneously involved in the same projects from its first conception.

The classical technology-push model of innovations fit the profile of successive generations of technology that have been dominant in the nineteen fifties and sixties. However, Sarmento Coelho proposed a circular model to capture the range of incremental innovations that we currently find in so many products, and whereby each innovation provides the incentives to look for another new combination, perhaps even with better properties.

Kamoche and Cunha (2001) identified four dominant styles of innovation processes. The first is the sequential style, neatly working from phase to phase, for which they used the metaphor of the relay race. The second is the compressed style, as it is to be found in the very successful Japanese models of innovation. For this particular style they used the metaphor of the accordion; separate phases were pressed together and all aligned into the same direction simultaneously. The third style is the flexible style, embracing change as the creative moment. Here, the market and the stage of technology pose new questions, and each time they open new windows of opportunity. The metaphor is the rugby game in which the action of the players actively anticipates on future possibilities. The last style is captured in the word improvisation. This style is based on experimentation within given technological formats and tries to find a balance between flexibility and the structure of the technology at hand to explore and exploit the full potential of a given field. The metaphor for this particular style is the jazz-improvisation.

These notions, which we discussed extensively in section 2.4.3, are particularly relevant in the characterisation of the differentiation and specialization process in the idea-innovation chain.

In the graph opposite we depicted three models. The first (depicted under A) is the classical idea-innovation chain, in which an idea, starting in basic research has to pass the stages of applied research, product development, manufacturing, marketing and sales, before it is on the shelf as a finished product.

Yet, today's products are only rarely the result of one single idea-innovation chain. Products (especially in the assembly industry) are increasingly the result of the complex interplay of a great number of separate idea-innovation chains, each to produce a specific piece of technology, a particular part, a semi-finished product or a specialised service. It needs for instance, several idea-innovation chains to develop a modern cell-phone. One to develop the display, another to design the antenna, and a third to develop the housing and the push buttons. This process of vertical differentiation is depicted under model B, where we find several specialised idea-innovation chains to develop one finished product.

Model C depicts the process of horizontal differentiation. The step from basic research to applied research may be too big and needs another sub-phase to bridge the gap between the two phases. Or the phase of quality-control is added between manufacturing and

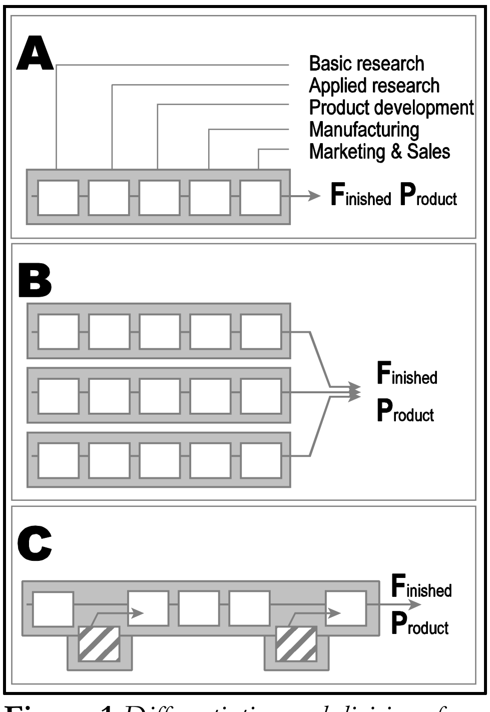

Figure 1 *Differentiation and division of labour along the idea-innovation chain*

marketing. Adding new phases to the processes lengthens the steps from an initial idea to a finished product.

Finally, the phases of the idea-innovation chain may be divided over different organizational units, possibly departments within the firm, or different independent organisations, and they may even be located in different countries. This is what we call the division of labour.

		Telecommunication				Agriculture/food & chemistry cluster			
		1910	**1940**	**1970**	**2000**	**1910**	**1940**	**1970**	**2000**
Differentiation	*vertical*	*low*	*relatively low*	*relatively low*	*high*	*low*	*low*	*low*	*relatively low*
	horizontal	*low*	*relatively low*	*relatively low*	*moderate*	*low*	*low*	*low*	*moderate*
Division of labour		*low*	*relatively low*	*relatively low*	*high*	*low*	*low*	*low*	*increasing*
Mutual dependency		*linear*	*linear*	*linear*	*linear / flexible*	*flexible*	*flexible*	*flexible*	*flexible*
Coordination	*within the company*	*hierarchy*	*hierarchy*	*hierarchy*	*hierarchy network*	*hierarchy*	*hierarchy*	*hierarchy network*	*hierarchy network*
	between companies	*market*	*hierarchy*	*hierarchy*	*market*	*networks*	*networks*	*networks*	*market networks*
Mobility of	*workers*	*low*	*low*	*low*	*high*	*low*	*low*	*low*	*moderate*
	staff & management	*low*	*low*	*low*	*moderate*	*considerable*	*considerable*	*considerable*	*moderate*

Table 39 *The organizational architecture of the idea-innovation chain in two sectors (1910 - 2000)*

In telecommunication we found that the degree of vertical differentiation was relatively low until the nineteen nineties. Most of the products may indeed have reached a high degree of sophistication, but they were based on relative simple electromechanical technologies. A telephone-set for instance contained a few simple electromechanical parts as a dial, several coils, a carbon microphone, wiring and a small speaker. All these parts were assembled in a plastic housing, and there was hardly any variation in models and even fewer in internal technology. The cable-industry was a typical low-tech industry, in their own words a wrapping-industry, with only few variations. The most sophisticated parts were the switches, but even their technology was relatively simple. This pattern started to change with the advent of computer technology and still later, with the introduction of digital technology. Electrical parts were replaced by electronics, signals were transformed from analogue to digital (and back again). New equipment introduced transistors, semi-conductors, chips, computers and software. If one would dismantle a telephone made in the nineteen sixties and compare it to a product made in the nineteen nineties, one would see a world of difference. More parts, many different materials, smaller parts, all assembled on a complex printed circuit board. Vertical differentiation has indeed increased sharply. Today's equipment is the product of several complex idea-innovation chains for each singular part, and even within them several more chains.

Horizontal differentiation has also increased through the change of the technological paradigm. Meeting market requirements was increasingly important in a liberalising market and the classical linear organisation of the idea innovation, which was still good enough for a highly standardised production process of the nineteen seventies, had serious drawbacks. Firms have split up the innovation process to meet this new challenge. Philips for instance, introduced the phase of advanced development to bridge the gap between basic research and customer demand. It also actively involved customers in the R&D process to identify the main design-parameters for future equipment. On the one hand the process has been extended by the introduction of new phases between existing ones and these have lengthened the idea-innovation chain. On the other hand there is a process towards compression of the idea-innovation chain. The process is no longer organised as a purely linear sequence of phases; departments are actively invited to participate simultaneously in the same projects, thus allowing a project to move back and forth along the phases of the idea-innovation chain. This process is not typical for Philips; each of the telecommunication companies tries to improve the innovation process and increasingly involves customers as a basic frame of reference for new products.

Division of labour has increased significantly in the telecommunication sector. The classical telecommunication companies were used to produce all the elements for their products in-house, but that is no longer the case. Companies fill their shopping basket where the price/quality ratio is best. They basically do the same with the organisation of the idea-innovation chain. Equipment-design may be located in the Netherlands, but production, or other phases of the idea-innovation chain may be located elsewhere.

We basically found three tendencies in the telecommunication sector. First, the phases of the idea-innovation chain do no longer take place at the same place. Basic and applied research are usually concentrated in the home country, whereas production and applications are produced where the cost-efficiency is highest, and this opened a range of opportunities for entrepreneurial firms. Second, there is the tendency towards compression of the idea-innovation chain, with an increasing overlap between the phases. Time to market has become crucial for telecommunication research and a compressed organisation of the idea-innovation chain can speed up the innovation process. The importance of market-information has increased and sales and marketing departments are currently much stronger involved in the initial phases of the research process than ever before. Today they function as an intermediary between user and producer. Third, firms add functional departments between basic research and applied research and thus try to bridge the gap between technological advancement, market demand and production systems

In the agriculture, food and chemistry cluster we found a different pattern. The farmers-community, the food, chemical and pharmaceutical industries have traditionally been intertwined in complex production chains, however, with relative stable characteristics. The breeding of best quality cattle was a matter of patience and (mostly) tacit knowledge. The slaughtering of cattle was organised as a rather stable technology and the products of that process had also a sense of stability. Meat was used for consumption, and fat, bones, hide and offal were used in several other products, such as gelatine and glue, shoes and clothing, animal and pet food, and of course many applications in the pharmaceutical industry. Each of the production phases had its own dynamism, but by and large these were less intertwined than in the telecommunication industry. Vertical differentiation was traditionally low. This is not surprising in a process-industry. Also, horizontal differentiation used to be low. Research was organised in a classical way as a linear sequence of innovative activities. The latter characteristic however, has changed due to the change of the technological paradigm. New sub-phases have been added. Especially on the interface of basic and applied research we find new research tasks, with a specific demand for specialised research services and products, placing highly specialised phases between basic and applied research activities. Many renowned firms have out-sourced specialised research, because specialised companies may have a better size, scope and scale to offer research products and services at competitive prices. The large food, chemical and pharmaceutical industries do not longer solely rely on their own research capacity, but out-source research towards specialised companies, thus forming a large virtual laboratory with a range of services, supplied by a range of participants. Playing the field, and knowing where to get the best has become crucial important in modern biotech research.

The division of labour used to be unequivocal and relatively simple within each line of production. The meat-industry for instance had its own, relatively stable interactions and research links within the production chain, and this was basically the same for other product-groups. In each line we find the participation of industry, academia, farmers and research institutes. In recent years we find the tendency that the division of labour is increasing. The production of flavour-enhancers for instance, used to be and an integral part of the large firms in the food-industry, but these industries have gained independence. We find the same process in the fermentation industry. Former parts of large companies have become self-sufficient, and provide specialised services to a range of customers. On the one hand this is due to the change of the technological paradigm, but the influence of modern ICTs is, on the other hand, equally important. Specialised research communities tend to become virtual communities and they locate where conditions are best.

If we compare where innovative activity comes to the surface along the idea-innovation chain in the form of innovative and entrepreneurial companies, we find a remarkable difference between the two sectors. In telecom these activities concentrate in the production and application phase whereas in biotech they concentrate at the interface between basic and applied research. How can we interpret these differences? On the one hand we can follow Dodgeson's analysis (1991) (discussed in more detail in section 2.4.7). He found in the US semiconductor industry that the large industries develop innovations, basically for their own needs and purposes. However, new technology-based firms spin off of these large industries to commercialise the innovations, and often these small companies develop into a specialised supplier for the large industries. In the Netherlands we saw a similar kind of pattern in the optical fibre industry. POF for instance, started as an experimental plant under the wings of Philips research, but gained independence to develop as a commercial business. Currently it is part of the Draka Holding.

Dodgeson found that the entrepreneurial firms in biotechnology did not start as a spin off of the industry, but as a spin off of universities, graduate schools and research institutes. The large chemical and pharmaceutical firms do not invest so much in research, but rely on the research and learning capacity of the small and flexible new technology-based firm. These firms are usually positioned around the interface of basic and applied research and they can prosper, because it is an attractive sector to invest venture capital. Thus, the type of sector is the main determinant for where innovativeness concentrates. It is most likely that a typical assembly industry with its complicated puzzle of separate idea-innovation chains will have a different profile than the process industry. It is most likely that the assembly industry has a much higher degree of vertical differentiation, because out-sourcing of production is far easier than in a typical process industry. However, the degree of horizontal differentiation is higher in the latter industry, because small innovative companies will usually have a better size, scope and scale to perform specialised tasks in a cost-efficient way. The telecommunication industry has traditionally developed as an assembly industry. The liberalisation of the telecommunication market and the introduction of digital and optical equipment on the market, have even reinforced this profile.

Each movement towards more differentiation and specialization calls for coordination and integration. One can characterise economies by their dominant principle of coordination, the hierarchy, the market or networks

The telecommunication industry was basically organised in two hierarchies; the monopolistic public hierarchy on the side of the operator, and the classical vertical integrated hierarchy on the side of the telecom equipment industry. This system has existed until the end of the nineteen eighties, when the monopoly was dissolved and market competition was allowed. This has created new interdependencies in the firm and between firms. The incumbent was gradually divided in several new hierarchies and the hierarchic coordination principles were partly replaced by more market and network-oriented principles. Many intra-firm relations were replaced by inter-firm relations. The construction of new telecom networks for instance used to be one of PTT's tasks, however, PTT has hived off this task to private partners. PTT/KPN telecom is now a customer, in fields where it used to be a producer. Hence, relations between companies are no longer coordinated by the hierarchy but rather by market-relations.

Another mechanism for coordination and integration is the flow of people through different organisations, i.e. the mobility of workers and the mobility of staff and management. Mobility was relatively low under the old electromechanical paradigm of the telecom monopoly. There were only few firms and it was uncommon to switch from one employer to another. Mobility within the firm was stronger, especially for staff and management. Many executives of the former PTT have started their careers in research where they learned the tricks of the trade. 'Loaded with knowledge' they were appointed on management or technical positions in the PTT organisation, which allowed for an easy flow and exchange of knowledge within the firm. This pattern changed after the opening of the telecommunication market. Many new firms entered the stage and the labour-market was extremely tight. Job-hopping was the rule during the nineteen nineties, rather than the exception.

Coordination in the agriculture, food and chemistry cluster fits a different profile. The large food and chemical industries were organised as hierarchies, but idea-innovation chains often reached beyond the boundaries of the hierarchy. By and large we can say that networking was much stronger developed in agriculture than in industrial sectors. The change of the technological paradigm has introduced several new players, but it did not change the dominant coordination principle. Networking is still very important, especially because many firms are set up as a hybrid firm at the interface of academia and industry. However, there is also a tendency that relations are increasingly governed by market-relations, which is especially the case in specialised research products or services.

The mobility of workers used to be rather low, but is currently increasing. This is however, not so much due to the change of the technological paradigm, but rather the result of a general process towards growing internationalisation of markets, which has led to numerous rationalisation-processes in the industry. Mobility of staff and management has traditionally been somewhat higher in agriculture than in telecom. The larger cooperatives highly valued the independent position of staff and management and therefore recruited higher personnel from outside the region. Next to independence, these highly skilled workers brought new views, technologies and methods into the firm. Yet, specialization, differentiation and upscaling of activities have made these arguments obsolete. Currently there is a moderate degree of mobility in the cluster, largely comparable with other economic sectors. However, if we narrow our approach to the biotech industry, we find that numerous scientists have worked abroad, many of them in the successful biotech areas in the UK and the USA. This has two important implications. First, these scientists bring new knowledge in the Dutch research cycles, but second, they bring new management-approaches. Especially the USA has a different attitude towards entrepreneurship and some scientists are 'infected' by the entrepreneurial virus. Thus, they bring scientific-skills as well as management-skills to the Netherlands.

9.2.3 The institutional environment

The innovative activities of firms are embedded in a variety of institutions that facilitate or hamper innovative and economic performance. In this study we have focussed on three institutions that provide resources to the sectoral idea-innovation chain. In doing so they structure the flows of money, knowledge and societal consent to the innovation system.

The first institutional system is the financial system which provides the resource that firms need to invest in more or less risky activities. This system also structures the type of innovative performance. For instance, if an innovative startup firm has easy access to risk-capital, and the availability of such capital is high, it is more likely to expected a risk-seeking attitude in the company, than if access to risk-capital is difficult and availability of such capital is low. In the latter case it is more likely that the company will err on the safe side.

The second institution is the knowledge system which provides the idea-innovation chain with knowledge, training and skills. A knowledge system that is strong in the generation and the dissemination of knowledge to industry will generally be more supportive to the innovative performance of a sector than a system that treats the academy and industry as strictly separated domains. The latter type of system will hamper an easy flow of knowledge and skills between domains.

The third institution is the regulatory system which demarcates the elbowroom for innovations and provides the incentives for innovation. It provides the norms, rules and values of what is acceptable or unacceptable for society. Rules and regulations may have various impacts. They may hamper the innovation process, because they do not allow to search beyond the borders of the acceptable. On the other hand they may support the process because they provide the clarity that is needed to assess future plans. The regulatory system provides legal security, and thus helps to cope with the uncertainties of the innovation process. However, regulations do not alway have such a morally-laden impact. Traffic-rules for instance, are morally neutral, and so is a range of technological rules, such as standards and technological norms. (We discussed the role of institutional environment extensively in section 2.5)

Much of the literature on 'national systems of innovation' has focussed on institutions as being a specific kind of organisation. This approach has reduced the financial system to banks, venture-capital funds and the stock market as discrete organisations, the knowledge system to schools, universities and research institutes, and the regulation system to law-books and contracts. However, this is a too narrow approach of institutions, because it neglects the underlying values and norms, which provide the general blue print for communication, interaction and trust between actors in the innovation process. Rather than discrete organisations, institutions are to be seen as sets of habits, routines, rules, norms and laws, which regulate the relations between people and shape human interaction (Johnson, 1992), and they may have a clear impact on the innovation process.

This is complex interplay, because discrete organisations affect and reinforce the organisational structure within the sector. The strength of the co-operatives is that its participants have faith in this institutional concept. In the same line of reasoning, it is most likely to expect that a farmer will go to the Rabobank for investments rather than to another bank, because the Rabo bank has developed considerable expertise in agriculture-related investments. In doing so the farmer reinforces the habit and strengthens the position of the bank. Also, trust has a special connotation in agriculture. The negotiation process in agriculture has developed some folkloristic elements, but is taken highly serious by farmers and cattle dealers. The process is 'adorned' with a fierce clapping of hands on both sides, and each clap is a seal, cutting off the way to retreat. The final deal is sealed with a firm handshake that has an impact which equals a written contract.

Institutions provide resources, help to structure information and behaviour in a system of innovation, and help to deal with the problems of uncertainty and risk. They provide stability in the patterns of social interaction, and reduce uncertainty for individual decision makers. Institutions tend to endurance and stability, but still they are also flexible, and change in accordance to changes in the technology. The liberalisation of the telecommunication market serves as an excellent example of how rule systems have changed in accordance to technological change from the classical electromechanical systems to the modern digital systems.

	Telecommunication				Agriculture/food & chemistry cluster			
	1910	**1940**	**1970**	**2000**	**1910**	**1940**	**1970**	**2000**
Social embeddedness	*narrow*	*narrow*	*narrow*	*relatively narrow*	*broad*	*broad*	*broad*	*relatively broad*
'Supply' of skilled labour	*sufficient*	*sufficient*	*sufficient*	*insufficient*	*sufficient*	*sufficient*	*sufficient*	*sufficient*
Education	*in company*	*in company*	*in company*	*in company*	*in sector*	*in sector*	*in sector*	*in sector*
Research funding	*n.a.*	*public*	*public & private*	*public & private*	*public/ private*	*public/ private*	*public/ private*	*public/ private*
Impact of regulations	*considerable*	*high*	*high*	*decreasing*	*moderate*	*moderate*	*increasing*	*increasing*
Role of associations in the provision of: training/ education	*none*	*none*	*minor*	*minor*	*major*	*major*	*major*	*major*
finance	*none*	*none*	*none*	*none*	*considerable*	*considerable*	*considerable*	*decreasing*
regulation	*none*	*none*	*none*	*increasing*	*low*	*increasing*	*considerable*	*considerable*

Table 40 *The institutional environment of two sectors (1910 - 2000)*

There are several important differences between the two sectors. The telecom sector was a 'technological island', with only few contacts to the outside world. It was a system of tight connections between the actors, well protected by a monopolized structure under state control. This structure was particularly inner-oriented. The monopoly was the first frame of reference, not the customer, and not even the supplier. Much of the education was organised within the company, and the influence of the company on its employees' social life was very strong. PTT had its own holiday parks, training centres and cultural events. PTT' brass band held a particular high reputation. This same basic pattern is found in Philips. Philips was important as an employer, but also important as a social beacon, with its own cultural centre, its systems for social support, its soccer and other sports club. But, in both companies it was in inner-oriented attitude. The basis for social embeddedness in the telecom sector was largely narrowed to the company.

This was a marked difference with the agriculture, food and chemistry cluster. Innovation in this cluster was embedded in complex networks, linking numerous actors to each other. Industries had ties to public and private research institutes, academia, vocational centres and schools, societal clubs, political parties, farmers and breeders, and economical entities in related business and industry. The involvement of farmers and breeders in agricultural co-operatives and other systems of joint-decision making was particularly strong. No economical sector was so open to the ideas of the statutory industrial organisation (PBO) as the agricultural sector. The explanation is in the historical importance of the agricultural and agro-industrial co-operatives. A wide variety of economical actors has started as a co-operative, such as banks, factories, purchase and sales co-operatives, auctions, or as a co-operative of co-operatives, the latter especially in quality control and research. This system of co-operatives has imbued the funding system, the knowledge system and in the regulation system. It developed rules about the basic quality for auctioned products, but it was also present in the board of the agricultural schools. It had its own financial system and there were numerous links between this system of co-operatives and important societal players, such as political parties, the clergy and the local communities. Thus, social embeddedness in the agriculture, food and chemistry cluster was particularly broad, involving actors from many different backgrounds.

This same pattern is reflected in the education structure. We already touched upon the fact that telecom education was largely based on 'in-company' training programmes. PTT developed an extensive system of training on the job and it had its own national training centres with a range of specialised programmes. The research lab was the place to start for the elite of higher educated engineers and technicians. Here they could learn the peculiarities of the technology, add their own skills and develop new skills to be used in future managerial functions. This was largely a 'closed shop' system in which loyalty to the company was highly valued.

Education in the agriculture, food and chemistry cluster was rather an 'in-sector' kind of project. Each level of education after primary school was organised under the responsibility of the Ministry of Agriculture. This goes for agricultural training (farmers, breeders), but also food sciences (butchers, bakers and several inspection functions). Education in these field was a world apart for long, largely separated from the general education and vocational system which was organised under the responsibility of the Ministry of Education and Science. It goes without saying that agricultural education was particularly rich in the number of links it held to local agricultural community, local craftsmen, specialised industries (esp. food and dairy products), and government agencies (inspections and quality control).

The supply of skilled labour did not pose a problem in telecom until the nineteen nineties. The liberalisation of the telecommunication sector allowed many new entrants onto the market, but all these firms were fishing in the same pond. The supply of skilled personnel has been lacking throughout the nineteen nineties. Only the collapse of technology and telecom funds brought relaxation on the tight labour-market. Several industrial research centres have closed and the market for skilled personnel is currently more balanced than during the telecommunication hype of the late nineteen nineties. The supply of skilled workers in the agriculture, food and chemistry cluster has traditionally been sufficient. The change of the technological paradigm did not bring drastic changes. Yet, the reach of the labour-market in the sector is increasingly international, but it is doubtful to attribute that development to the change of the technological paradigm, it is rather a general development that can be observed in many science-driven sectors.

Research is funded by public as well as private sources, however, with a marked difference between the two sectors. The division of roles in telecommunication was basically determined by the character of the tasks. Public tasks were supported by public research on the side of the operator, while the development of equipment was funded by the telecom-industry. These systems are complementary, but not necessarily intertwined. Yet, in the agriculture, food and chemistry cluster we cannot so easily use a similar division of roles along the character of the tasks. To substantiate this argument we return once more to the case of the cheese exports to the United Kingdom.

The British court had ruled that cheese should have a certain fat-percentage and this should be visible on the cheese. To enforce this policy in the Netherlands, there were basically two options. The first option was to put supervision in public hands. Supervision was a matter of public interest and enforcement should therefore be a public task. The second option was to put supervision in the hand of a private agency. The Netherlands chose the latter approach, as it turned out, for obvious reasons. Supervision as a public task would imply that each violation was liable to criminal law, but this also implied the risk that the courts could sentence offenders to a fine, probably lower than the profits they made from cheating. Therefore, the alternative was chosen and supervision was brought under private responsibility. Violation was brought under private law, which gave the possibility to impose fines, substantially higher than the profits made from cheating. Quality control was put in the hands of private research institutes, which were organised as a co-operative.

In the example discussed above we find a mixture of public and private tasks, as well as a mixture in funding structures. Research and enforcement were often intertwined functions, and private and public monies were used to fund these structures. This model of private and public research cooperation is gradually converging towards a system wherein public/private cooperation is the rule, rather than the exception. This tendency towards public/private cooperation is also apparent in the telecom sector (e.g. the Telematics Institute). However, in telecom it is a rather new model, whereas in agriculture it was built on established practice.

The impact of regulations has been high in the telecom sector, especially during the state-monopoly in telecom services. However, the load of regulation has decreased since the deregulation policy of the nineteen eighties, which has cumulated in the liberalisation of the telecommunication market, but is still considerable. The telecommunication market still is a regulated market with favourable conditions for new entrants and restrictions for established parties with considerable market-shares. OPTA, the independent supervisor monitors and controls the telecommunication market.

The impact of regulations in the agriculture, food and chemistry cluster was traditionally relatively modest, but has increased during the post-war years. The introduction of the new biotech tools has called for new regulation systems and the Netherlands was among the frontrunners in this field. By and large, this was a supportive system, especially because it provided clarity and legal security. A clear set of rules and regulations helped to cope with the problems of uncertainty. However, recently the tide has been turning. Ministries hold different attitudes regarding the desirability of biotech research. While some ministries try to accelerate innovativeness in the biotech industry, other ministries are pulling the brakes. This has eroded the predictability and reliability of government policy. Lack of clarity over future policy has paralysed biotech research, with devastating effects in agriculture, the food industry and the chemical industry.

The role of associations in telecommunication has traditionally been low. Yet, the change of the technological paradigm and the liberalisation of the telecommunication market have led to the founding of a new association of large-scale telecom users.

The role of associations in the agriculture, food and chemistry cluster has traditionally been much stronger. The associations were traditionally deeply involved in finance, education and regulation. In the new biotech activities we find a decreasing role of the old associations, but a new role for specialised biotech associations and venture capital funds.

	Telecommunication				Agriculture/food & chemistry cluster			
	1910	1940	1970	2000	1910	1940	1970	2000
Economic orientation	*public service*	*public service*	*public service*	*growth*	*growth*	*growth*	*growth*	*growth*
Market	*open*	*open*	*sheltered*	*semi sheltered*	*open*	*open*	*open*	*semi sheltered*
Players in the market	*few*	*few*	*few*	*increasing*	*numerous*	*numerous*	*numerous*	*numerous*
External relations	*few*	*few*	*few*	*increasing*	*numerous*	*numerous*	*numerous*	*numerous*
Pattern of specialization	*transmission*	*transmission*	*transmission*	*transmission & services*	*high volume/ low prices*	*high volume/ low prices*	*high volume/ low prices*	*high volume/ low prices*

Table 41 *Sectoral characteristics of two sectors (1910 - 2000)*

9.2.4 Sectoral characteristics

In view of our findings in technology, the organizational structure and the institutional environment, we can now isolate some sectoral characteristics and how they have developed over the years. The telecommunication market may have been open until the nineteen forties, but the character of equipment was such that there were very stable, monopoly-like relations between the operators and suppliers. The telecommunication sector used to be rather closed, traditionally with rather narrow cluster characteristics, only few players in the market and only a limited number of external relations. The liberalisation of the telecom market has put an end to this stable character. Openness has increased, an increasing number of actors has been involved, and there are numerous links to the outside world today. Telecommunication has changed from the public utility that is was before the liberalisation into the growth-market of the nineteen nineties.

The agriculture, food and chemistry cluster has a tradition of openness, involving numerous actors and numerous links to the outside world. The economic dynamism is especially oriented towards growth in a semi-sheltered market. The cluster also differs from the telecom sector because change in the technological paradigm was much easier absorbed by existing institutional systems.

The pattern of specialization in Dutch telecommunication research and production has radically changed as a result of technological change. Its past orientation was on transmission and system management. Its current orientation is rather in the development of services and applications.

In the agriculture, food and chemistry cluster we still find a strategy focussed on the production of ever higher volumes in a cost-efficient way. Its products can be offered in large quantities at competing prices. This is a persistent pattern and change of the technological paradigm did not affect this orientation.

9.2.5 System character

In the previous sections we discussed the typical features of the national-sectoral system of innovation in Dutch telecommunication and biotechnology, regarding technology, the organizational architecture of the idea-innovation chain, the institutional environment and the sectoral patterns of specialization. In the comparison we found numerous differences between the two sectors. Yet, are the differences that we found sufficient to substantiate our position that innovation should be studied from a national-sectoral perspective? We tend to believe so, because the profile of the two sectors does not fit a general overarching model, which is equally valid for the two sectors. Our study indicates that the two sectors have numerous differences. And indeed they form a system; they have an internal and systemic coherence. The limited number of actors in telecom, the few outside links, the rather closed community, which had organised education within the company, this all fits the monopolised structure of the telecom sector. Furthermore, the linear organisation of the idea-innovation chain is in line with the hierarchic organisation of operator, service providers and the industry.

Similar relations are to be found in the agriculture, food and chemistry cluster. The importance of networks fits with the broader societal embeddedness, the important role for associations, the large number of players and external relations in the innovation process. All these indicate a systemic internal coherence within the sectoral systems. These findings give reason to believe that reactions to chance, problems, opportunities, cooperation and difficulties are influenced by sector-specific patterns of interaction and social behaviour. Actors in the agriculture, food and chemistry cluster who are faced with some problem, will search for solutions in networks, while actors in the telecommunication sector will search for solutions in the hierarchy of the firm. This is a rather persistent pattern and still to be found today, despite liberalisation of the sector and despite numerous new actors.

9.3 Final remarks

9.3.1 The time dimension: path dependence

The innovation system as we find it today is the mixed result of current challenges/constraints in the current environment, past experience and the organisations and institutions created by it. We took up the thread of our historical analysis around 1910, and found a remarkable persistence of the system in both sectors. The most important change was that of the technological paradigm in the nineteen eighties and in its wake -in the telecom sector- the liberalisation of the telecommunication market. It made the former monopoly obsolete and allowed new entrants onto the market. The technological change from classical to modern biotechnology has not been as drastic as the change in the telecommunication sector. The introduction of digital equipment made analogue systems obsolete, while the modern tools in biotechnology were rather an extension of the biotech toolbox.

The structure of an innovation system is highly imbued by past experience and path-dependent trajectories and the institutions they have created. Some are the consequences of relative small and contingent events in the past, others are set in motion by the change in large technological systems. Yet, it pays off to continue a particular path of development, especially when large setup- or fixed costs (sunk-costs) have been made into a certain direction and it follows that further investments are made in that same direction. Furthermore, learning effects appear in the operation of complex systems, which leads to higher returns from continuing use, just as coordination effects appear when more actors adopt the same direction for further development. Thus, a particular path of development tends to reinforce and strengthen the system, and tends to exclude alternatives. The impact of these systems is particular strong, such to the degree that they create adaptive expectations when people are in doubt about the choices they have made. People tend to stick to their choices, because future expectations lead individuals to adapt their actions in ways that help to make those expectations come true. Hence, it follows that there is an element of self-fulfillingness in their choices (cf. Arthur, 1994; Pierson, 2000). Path-dependence is a self-sustaining force leading to recurrent and sector-specific patterns.

In this section we will discuss examples of path-dependent trajectories in technology, organisation structure, institutional environment and sector specialization.

Technology

In section 4.2.3 we discussed the pupinisation of ground cables. This was a technology meant to stabilise a telecom signal over distance. At the time of introduction, in the early twentieth century, there were no suitable technologies available to measure the frequency-characteristics of the cable and it was hard to decide which interval to choose between two pupin-coils. The only instrument was the human ear and it finally turned out that the Dutch approach in pupinisation was based on two methods; coils with a self-inductance of 65 mH at 3000 metre intervals and coils of 130 mH at 1500 metre intervals. This resulted in a cable-impedance of 800 ohm. This system worked well, but was problematic, because most of the telecommunication networks abroad were based on a cable impedance of 600 ohm. It separated the Dutch system from the international system and this has lasted into the nineteen seventies.

This had also consequences for the Dutch telephone sets. The Dutch telephones were based on 800 ohm-technology, which separated them from models abroad. But this being the case, why not develop a country-specific solution to improve the quality of the signal? Most of the countries abroad choose to increase sound-volume, but the Dutch choose a different solution. Within the 800 ohm-technology they choose to improve audibility by changing the characteristics of the microphone. It resulted in a telephone, with excellent audibility characteristics, but a much ‘softer’ sound-level. This did not pose a problem in the Netherlands, but it -again- separated the Dutch telephone from systems abroad. Solutions were usually sought in line within country-specific characteristics and these country-specific differences were only eradicated by the decision to digitalise the telecommunication network and to accept international standards.

Organisation

It is not surprising that the agriculture, food and chemistry cluster has a network-like structure of decision-making. Technological innovations such as the introduction of chemical manure may have had a strong impact on productivity, but the effect of organizational and institutional innovations could easily equal the importance of technological innovations. The co-operative was an aggregation of individual resources which gave the participants access to desirable resources that they could not access or achieve on their own. But what is more, the participants in the co-operative held control over these resources. The key to success was an extensive network between these co-operatives.

The telecom-sector rather tended to solve its problems in the hierarchy of the firm, or the hierarchy of the operator. One might have expected that the liberalisation of the telecommunication market allowed new entrants, and thus might have led to more market-based solutions. However, that was not always the case. Take for instance the case of the Dutchtone network. The roll-out of the Dutchtone mobile network, in which France Telecom is one of the players, is carried out and coordinated by the French incumbent, who flew in a team of engineers and technicians, rather than to involve local actors. Even Alcatel, the 'home-supplier' of France Telecom and active in the Netherlands, played no role whatsoever in this project. It indicates that the monopolised structure of European telecommunication has left its traces in the hands and the heads of the workers.

It also seems to indicate a pendulum motion. The former hierarchies were broken down by the liberalisation of the telecommunication market and several new entrants got active on that market. Five mobile operators started in the Dutch market, but it remains to be seen if this will still be the case in the years to come. Operators need to have a 'critical mass' to be competitive and currently it seems that the telecommunication market is concentrating again, with several of the former (international) incumbents as the major league players.

Institutions

The structure of the institutional resources in the two sectors, such as the financial, knowledge and education, and regulatory system, was strongly influenced by the sector-specific characteristics. The development of vocational systems in the two sectors was not so much the result of an in interest of the education system in agriculture or telecom, but rather a result of the interest of each of the two sectors in education. Each sector found its own, sector-specific solution. The telecom-sector relied on self-study and in-company training, but soon left basic vocational education to be the task of the general education structure.

In agriculture it was the elite of industrialist, clergy, local gentleman-farmers, and -still later- the co-operatives that took the lead in agricultural education. From the beginning there has been a remarkable difference between the general education systems and agricultural education. The former organised courses all-year round, while the latter concentrated its courses exclusively during the winter-time, when work on the farm was low. This system of agricultural training was extended time and time again, with special schools for dairy farms, horticulture, floriculture, market gardening and cultivation under glass. The system was later extended to vocational training for bakers, butchers and several inspection services. Yet, this system was largely separated from the general education system. It took until the early nineteen seventies before the system started to converge with the general education system, but still, the flow of money for this specialised system flowed from the Ministry of Agriculture, rather than the Ministry of Education.

Modern biotech education has partly shirked out of the traditional pattern of agricultural research. Its domain is much wider than just agriculture and involves healthcare, chemistry, pharmaceuticals and environmental care. The knowledge-base in these field is not exclusively Dutch and many scientists have been educated abroad. Opening up the system has allowed new flows of knowledge, but also new flows of money and regulation.

The exclusiveness of the agricultural sector, with the Ministry of Agriculture as its pivot, is gradually eroding. The main frame of reference for the regulatory system used to be the strengthening of agricultural production and the sheltering of the export-position of the Netherlands. Yet, in recent decades several other Ministries have interfered. The Ministry of Housing, Spacial Planning and the Environment has for instance developed an active environmental care policy, and the use of lands for bio-technological field-trials is restricted with a system of licences. Similar processes are also to be found in telecommunication. Regulation and supervision used to be the exclusive domain of the Ministry of Transport, Public Works and Water Management, but that is no longer the case. OPTA may have been erected as the independent supervising agency for telecommunication and post, but its societal role is gradually converging with that of the NMa, the Dutch Competition Authority, that was developed by the Ministry of Economic Affairs. This changed the perspective. Regulation used to be a technical matter, aiming at safeguarding the technical integrity of the Dutch telecommunication system within its system of national standards. Regulation today is aiming at creating open market-conditions, within the limits of open, international standards.

Sector-specific patterns were also present in the provision of money. The Raiffeisen- and Boerenleenbanken (which later merged into the RABO bank), were set up as co-operatives, to support the modernisation process in agriculture and supply money for agricultural investments. But supplying money is that is not the only thing they did. The banks also encouraged (and disciplined) the farmers towards the modernisation project, and thus developed considerable power as an important player in the encompassing expert-system in agriculture. Yet, it fitted the general pattern of the network-like structure of the sector.

However, modern biotech research is using different sources of research funding. The internationalisation of the sector is parallelled with the introduction of new financial instruments, such as seed and venture-capital, and currently we find that pioneering biotech research is mainly funded by these new resources.

Sector specialization

Why is the Netherlands strong in floriculture and horticulture? Why are Dutch companies among the leading companies in seeds? And, why is that Dutch biotech research developed such a strength in agricultural research? The most obvious answer lies in the past. The remarkable performance of the Dutch agricultural community has been reported since the seventeenth century and it held that position throughout the years. Innovation in agriculture is a result of the cumulative knowledge of centuries combined with the ambition to stay on top. The export orientation of agricultural products has led to a constant stream of by-products which could be used as raw material for other lines of products. Much of the pharmaceutical industry was built on the use of animal products, but the same industry also specialised in animal healthcare. AKZO/Nobel is among the world-leaders in animal healthcare products, which is not surprising, because there is so much life stock to attend to. It is obvious that the Dutch specialization in agriculture has been the engine in many adjacent sectors, such as the food, chemistry and pharmaceutical industry. In this context it is not surprisingly that modern biotech was welcomed, particularly in the agricultural field, because it offered so many high-pitched promises. Furthermore, the first fields to explore in this new technology were directly related to agriculture. The Netherlands had all the trump-cards for successful biotech research, but the acceptance of modern biotech-applications faced more public resistance than was foreseen.

By and large we can say that there was a considerable degree of continuity in the two sectors. Biotech innovations strengthened the research position in the agriculture, food, and chemistry cluster. In telecom we find that research in transmission technology remained high on the agenda.

We found a relatively high degree of continuity in the organisational structure. The agriculture, food and chemistry cluster kept its highly developed system of numerous networks and cooperation. The telecommunication sector opened and allowed new entrants onto the market, but currently we find a tendency to find organisational solutions in the hierarchy of the large telecommunication companies.

Yet, continuity was relatively low in the institutional environment. Internationalisation has not only widened the scope op research, but it also actively utilised new sectoral resources. The classical systems for the provision of research money were gradually extended by new instruments, such as seed and venture-capital. In the regulatory structure we find that national rule-systems are replaced by international rule systems. The European Union has become active in many fields and provides the general framework for national legislation in many fields. No longer are the standards for large technological systems defined by national standardisation authorities, but rather by international agencies. In the knowledge system we find virtual communities of researchers that reach far beyond national borders.

9.3.2 The space dimension: global or national

Does the nation still matters in a world where researchers can easily communicate through modern information and communication technologies (ICTs) and where production is dispersed over so many countries? Can we still speak of a truly national system of innovation, if activities are organised where resources are available, cheap or not hampered by regulations? Is it for countries still possible to create competitive advantage? We believe so. Any country can use its own resources and potential to create favourable conditions. The developing countries have skilfully exploited the advantage of low wages, but they can only hold that position when they are able to innovate effectively in production technology. The ‘old’ countries usually hold a strong position in research and development, because they already have the advantage of cumulative knowledge and a well-developed system of knowledge production and knowledge dissemination. Knowledge is indeed a matter of cumulative learning and most of the western-European countries have reached high levels in this respects. They have developed an institutional environment with sectoral resources that aim to be supportive to innovation and economic development. Some have the advantage of a strong educational system, which easily links industry and academy. Other countries are strong in funding system or have a supportive regulatory climate. The best performance is to be expected when the three institutional systems we discussed in this study (money, knowledge and regulation) are mutually reinforcing. The Dutch agriculture, food and chemistry cluster has been able to build such synergetic advantage. The determination of the expert-system in the execution of the modernisation project was built on the skills and institutional structures that it has developed in the past. The strength of the system was that all energy was directed to meet the requirements of the modernisation project.

9.3.3 National-sectoral systems of innovation revisited

This finally leads us back to the initial question: Do national-sectoral systems **exist** and **do they matter**? Our answer is confirmative. Based on the evidence collected in this study we can say that there are systemic differences between the two sectors. These differences are apparent in the ways the sectors treat technology, how they organise innovative activity along the idea innovation chain and how the institutional environment provides sectoral resources to the innovation system and shapes social and economical interactions between the actors.

Does this finding, then, undermine the relevance of the national system of innovation approach? We believe not. Our sectoral approach is rather to be seen as an addition to the more general notions of the national systems of innovation approach, however, offering more precision, a deeper insight and understanding of the mechanisms that constitute an innovation system in any given country. This is especially relevant because the impact of generic policies may work out differently in economic sectors. A national-sectoral approach of innovation systems holds the promise that policies can be tailored to size and scope of economic sectors to increase their innovative performance.

Summary in Dutch / Samenvatting

Het is moeilijk om het verschijnsel *innovatie* te vangen in een formele theorie. De Oostenrijkse econoom Joseph Schumpeter (1912; 1934) was een van de eersten die het innovatieproces op wetenschappelijke wijze trachtte te doorgronden. Aanvankelijk dacht hij dat innovaties het resultaat waren van de creativiteit en doorzettingsvermogen van ondernemende uitvinders. Weliswaar konden die niet in de toekomst kijken, maar ze waren bereid om alle moeilijkheden van het innovatieproces onder ogen te zien. Innovatie zag hij dan ook vooral als het resultaat van hun toewijding en doorzettingsvermogen. Aan de ene kant zag hij bijzondere individuen, die met hun creativiteit werkelijk in staat waren om iets nieuws te creëren. De grote Amerikaanse uitvinders en ondernemers van het begin van de vorige eeuw spraken zeer tot zijn verbeelding en hij sprak dan ook van de *heroic entrepreneur*, de heroïsche ondernemer-uitvinder. Aan de andere kant zag hij ook een heel legertje van imitatoren die in het kielzog van de grote ontdekkingen probeerden hun graantje mee te pikken. Innovatie bleef ook niet meer het werk was van vindingrijke individuen, maar werd in toenemende mate geïnstitutionaliseerd in de speur- en ontwikkelingsafdelingen (R&D) van de grote ondernemingen.

Maar steeds was er nog geen goede verklaring voor het verschijnsel innovatie. Waarom was het ene land beduidend innovatiever dan het andere? Was dat alleen maar een kwestie van technologie, of waren er ook andere factoren in het spel? Het feit dat landen verschillen in hun innovatieve prestatie is onderwerp geweest van veel landenvergelijkende studies. Lundvall (1992) heeft erop gewezen dat landen niet alleen verschillende productiesystemen hebben, maar daarnaast ook verschillen wat betreft hun institutionele omgeving. Ze verschillen in taal, geschiedenis en cultuur. In zijn baanbrekend onderzoek naar nationale innovatiesystemen (NSI) heeft hij voorgesteld om het onderzoek te concentreren op een analyse van de interne organisatie van bedrijven, de relaties tussen bedrijven, de institutionele opzet van de financiële sector, de rol van de publieke sector, en variabelen als R&D intensiteit en R&D organisatie. Van Waarden (1998) heeft er op gewezen dat in de structuur van het samenspel tussen organisaties en instituties wellicht de sleutel verborgen ligt voor een verklaring van de innovatieve prestatie van een land

Een tekortkoming van de onderzoeken naar nationale innovatiesystemen is dat ze zich teveel richten op de verschillen tussen landen en daardoor gemakkelijk voorbijgaan aan verschillen tussen sectoren. Nelson (1993) legt de vinger op deze zere plek en wijst erop dat het idee dat er zoiets als een nationaal innovatiesysteem bestaat, veel meer uniformiteit en verbondenheid suggereert dan in de werkelijkheid wordt aangetroffen. Wat vaak wordt gedefinieerd als een *nationaal* innovatiesysteem, blijkt toch sterke *sectorspecifieke* trekken te hebben. *Sectorale* verschillen worden aangetroffen tussen bedrijven, onderwijssystemen, wetgevingsstructuur en overheidsbeleid. Iedere sector blijkt voorts zijn eigen geschiedenis, cultuur en instituties te hebben. Met Nelson delen wij de opvatting dat de factoren die zorgen voor gemeenschappelijkheid in een land óók in hoge mate de gemeenschappelijkheid bepalen van afzonderlijke bedrijfssectoren, maar we verschillen met hem van mening als dat zou betekenen dat men landen op willekeurig welke economische sector kan vergelijken. Iedere sector draagt weliswaar kenmerken van het nationaal systeem, maar het omgekeerde is veel minder het geval. De dynamiek in de auto-industrie is een andere dan wordt aangetroffen in de farmaceutische industrie, de textiel industrie of welke andere sector dan ook. Als men de innovatieve prestatie van landen zou vergelijken aan de hand van willekeurig gekozen sectoren, dan zou dat gemakkelijk tot verkeerde conclusies kunnen leiden. Daarom zijn wij van mening dat de zeggingskracht van NSI-onderzoek zal toenemen, als de analyse berust op een vergelijk van overeenkomstige economische sectoren. Wij pleiten daarom voor innovatie onderzoek, dat niet alleen de *nationale* karakteristiek bestudeert, maar óók de *sectorale* factoren in ogenschouw neemt. Met deze studie willen wij de literatuur over nationale systemen van innovatie willen uitbreiden tot een *nationaal-sectoraal systeem van innovatie* (in het vervolg aan te duiden als NSSI).

Om dit standpunt te onderbouwen hebben wij twee sectoren bestudeerd, die op een aantal punten sterke overeenkomsten vertonen zijn. In beide sectoren worden veranderingen vooral bepaald door technologische ontwikkeling en deze zijn weer het gevolg van wetenschappelijk onderzoek. Verder is het economisch groeipotentieel van beide sectoren nadrukkelijk onderkend, voor het Ministerie van Economische Zaken reden om beide sectoren tot speerpunt van economische ontwikkeling te rekenen. Tenslotte hebben beide sectoren een belangrijke technologische verandering ondergaan in de zeventiger en tachtiger jaren.

Er zijn echter ook belangrijke verschillen. In deze studie zal ik de beide sectoren met elkaar vergelijken en aannemelijk maken dat het toevoegen van een *sectoraal* perspectief een noodzakelijke toevoeging is in het NSI-onderzoek, die de precisie en zeggingskracht ten goede komen.

In dit onderzoek gaat het om de telecommunicatie - en biotechnologie sector. Voor de telecommunicatie sector is het gemakkelijk het spoor te volgen door de geschiedenis. Telecommunicatie begon in het midden van de negentiende eeuw met de telegraaf en heeft zich geleidelijk ontwikkeld tot het stelsel zoals we dat vandaag aantreffen. Een belangrijke caesuur lag in de tachtiger jaren van de vorige eeuw, toen het klassieke, elektromechanische schakel- en transmissiesysteem werd vervangen door moderne, gedigitaliseerde apparatuur. Digitalisering heeft de weg bereid voor een reeks nieuwe producten en diensten, en liberalisering heeft vervolgens de telecommunicatiemarkt geopend voor een reeks nieuwe aanbieders. Vanuit het perspectief van vandaag is het nauwelijks meer voor te stellen dat luttele decennia geleden alle telecommunicatie producten en diensten uitsluitend werden aangeboden door de nationale PTT.

Ook in de biotechnologie sector is er sprake van grote veranderingen in de zeventiger en tachtiger jaren, maar het is hier veel moeilijker het spoor terug te volgen. De basisprincipes van wat we nu biotechnologie noemen, zijn al heel lang bekend. Al in de oudheid vinden we voorbeelden van mouten en fermentatie en ook het gebruik van gist in brood en bier was bekend. Bovendien hebben boeren sinds mensenheugenis geprobeerd om door kruising de karakteristieken van planten en dieren te verbeteren. De ontdekking van de DNA-structuur in de vijftiger jaren betekende een grote wetenschappelijke doorbraak, zeker toen wetenschappers er in de zeventiger jaren in slaagden om stukjes DNA uit één organisme over te zetten in een ander, niet gerelateerd organisme. Dat was het begin van wat we doorgaans moderne biotechnologie noemen. Op het ogenblik vinden we toepassingen in de voedselindustrie, chemie, farmacie, landbouw en in milieutechnologie. In de historische analyse die deel uitmaakt van dit onderzoek, hebben we ons vooral beperkt tot de landbouw en de voedselindustrie, omdat de biotechnologie juist in deze sectoren hoge economische verwachtingen had gewekt.

In het onderzoek hebben we gezocht naar de typische kenmerken van het NSSI in de telecommunicatie en biotechnologie sector, met betrekking tot de technologie, de organisatorische structuur, de institutionele omgeving en sectorale specialisatiepatronen. We hebben ons bovendien afgevraagd of er een systematische samenhang bestaat tussen de onderdelen van het systeem, en in welke mate het specialisatiepatroon wordt bepaald door de organisatorische en institutionele factoren. We noemden al dat de beide sectoren belangrijke technologische veranderingen hebben doorgemaakt in de zeventiger en tachtiger jaren. De vraag is dan hoe de beide sectoren hebben gereageerd op die veranderingen, met name of ze ook veranderingen teweeg hebben gebracht in de technologie, de organisatorische structuur, en de institutionele omgeving. Maar de voornaamste vraag is natuurlijk of het idee van een NSSI hout snijdt en ertoe doet. Kortom, levert het bestuderen van innovatiepatronen vanuit een *nationaal-sectoraal* perspectief een rijker beeld op, dan wanneer uitsluitend vanuit een *nationaal* perspectief wordt gekeken?

In het analysemodel dat ten grondslag ligt aan dit onderzoek onderscheiden wij drie niveaus die elkaar onderling beïnvloeden: de organisatorische structuur, de institutionele omgeving en de meta-institutionele omgeving.

Op het eerste niveau van de organisatorische structuur staat de vraag centraal hoe de sectoren hun innovatieactiviteiten gestalte hebben gegeven. Hoe hebben ze de weg georganiseerd die leidt van een idee naar een uiteindelijk product. Dit laatste proces wordt aangeduid als de 'idee-innovatie-keten' en daarin worden verschillende fasen onderscheiden. Klassieke beschrijvende modellen beginnen doorgaans bij de fase van fundamenteel onderzoek. Ontdekkingen en uitvindingen die daar worden gedaan, worden naar de volgende fase van toegepast onderzoek geleid, waar wordt bestudeerd wat voor toepassingen mogelijk zijn. Hier ontstaan de contouren van uiteindelijke producten. Het concreet vormgeven van producten en het inrichten van productieprocessen gebeurt in de fase van productontwikkeling. De productieafdeling maakt het product en de marketing en verkoopafdelingen brengen het product uiteindelijk op de markt. De klassieke modellen gaan uit van een lineaire opeenvolging van fasen, maar gaan daarin voorbij aan het feit dat ideeën voor nieuwe producten niet alleen volgen uit wetenschappelijk onderzoek, want ook marktinformatie levert nieuwe ideeën op. In moderne opvattingen van de idee-innovatie-keten, bewegen ideeën zich dynamisch, heen en weer langs de verschillende fasen, en leveren de fasen zelf ook (bijdragen tot) nieuwe ideeën. Deze toegenomen dynamiek levert een complex patroon van interacties op tussen de actoren in het innovatieproces. Innovaties worden niet meer uitsluitend uitgedacht in de bedrijven, maar steeds vaker door samenwerking van verschillende bedrijven. Daarom is in het onderzoek uitgebreid aandacht besteed aan de vraag hoe bedrijven samenwerkingsprocessen hebben ingericht (zowel *in* bedrijven, als *tussen* de bedrijven), hoe specialisaties ontstaan, hoe samenwerkingsprocessen worden ingericht, en hoe al die activiteiten gecoördineerd worden.

De organisatorische activiteiten staan echter niet op zichzelf; ze zijn ingebed in een institutionele omgeving. Wetten en regelingen bepalen de speelruimte die een bedrijf heeft om zich te ontwikkelen. In de biotechnologie sector bijvoorbeeld zijn er duidelijke grenzen gesteld aan wat maatschappelijk aanvaardbaar is en wat niet. In de telecommunicatie is er een uitgebreid stelsel van internationale standaarden. Ze leveren aan de ene kant een beperking, maar ze stimuleren ook om innovaties binnen duidelijk beschreven gebieden tot ontwikkeling te brengen. Wetten en regelingen helpen om de onzekerheid die inherent is aan het innovatieproces te reduceren. Een tweede belangrijke factor die in het institutioneel kader wordt bestudeerd is de financiering van innovatieactiviteiten. Het maakt nogal verschil of een beroep wordt gedaan op banken die traditioneel huiverig staan tegenover de financiering van risicovolle ondernemingen, of dat een beroep wordt gedaan op durfkapitaal, dat juist risicovolle ondernemingen zoekt. Een derde factor die is bestudeerd concentreert zich op de vraag hoe de innovatieprocessen omspringen met kennis. Uiteraard vinden we hier de rol van het onderwijs en de arbeidsmarkt, maar meer in het algemeen gaat het om de vraag hoe onderzoeksinstituten, universiteiten en industrie samenwerken om innovaties tot stand te brengen.

Ook de institutionele omgeving staat niet op zichzelf; hij is ingebed in een meta-institutionele omgeving waarin cultuur, traditie, geschiedenis, gewoonten, ethiek, normen en waarden de grondtoon bepalen van menselijke interacties. Sociaal en economisch gedrag ontstaat niet uit het niets. Het bouwt voort op tradities en gewoonten die in opvoeding, maar ook in het onderwijs, in de werksituatie en in het sociale verkeer worden overgedragen.

Deze drie niveaus beïnvloeden elkaar; ze kunnen worden opgevat als een genest systeem. Ogenschijnlijk zijn ze stabiel, maar er vinden wel degelijks veranderingen plaats, als voltrekken die zich soms maar heel geleidelijk.

Om ook deze veranderingen, waarvan de oorsprong vaak in het verleden gezocht moet worden, te kunnen begrijpen, hebben wij er voor gekozen om de systematische aanpak van Nederlandse innovatieactiviteiten in de beide sectoren vanaf hun oorsprong te volgen. Voor telecommunicatie ligt het begin in het midden van de negentiende eeuw bij de introductie van de telegraaf. De systematische aanpak van onderzoeksactiviteiten in de biotechnologie moeten vooral worden gezocht in de landbouw en voedingsmiddelenindustrie. De introductie van kunstmest aan het eind van de negentiende eeuw betekende in dat opzicht een belangrijke mijlpaal. De geschiedenis van de beide sectoren is behandeld in vijf hoofdstukken. Hoofdstuk vier behandelt ontwikkelingen van het begin tot aan de tweede wereldoorlog. Hoofdstuk vijf beschrijft de ontwikkelingen gedurende de periode van wederopbouw. Veel ontwikkelingen die voor de oorlog al in gang zijn gezet, zijn in de naoorlogse periode uitgewerkt en hebben geleid tot een opmerkelijk herstel van de Nederlandse economie, door van den Brink (1984) treffend aangeduid als *le miracle hollandais.* Dit hoofdstuk volgt het spoor tot aan de zeventiger jaren en daar ligt voor beide sectoren een belangrijke caesuur. In de telecommunicatiesector doet de computer zijn intrede, eerste nog als hulpmiddel bij analoge schakelsystemen, maar in de tachtiger jaren besluit de Nederlandse PTT de analoge techniek van elektromechanische schakelsystemen vaarwel te zeggen om plaats te maken voor digitale apparatuur. In de tweede helft van de tachtiger jaren wordt bovendien de omslag gemaakt van elektrische transmissiesystemen naar optische systemen, wat een aanzienlijke uitbreiding van capaciteit en snelheid betekent. De moderne ontwikkelingen in de telecommunicatie worden behandeld in hoofdstuk zes. Hoofdstuk zeven behandelt een soortgelijke caesuur in de biotechnologie. Traditioneel was de verbetering van organismen -of het nu om bacteriën, planten of dieren ging- gebaseerd op kruising van veelbelovende eigenschappen. Dit was een tijdrovend, maar bovendien onzeker proces, want het was nog maar de vraag of door kruising de gewenste karakteristieken ook metterdaad werden overgebracht. Met de recombinant DNA methode kon veel preciezer en bovendien veel sneller resultaat worden bereikt. Stukjes DNA konden nu van een organisme in een ander, niet gerelateerd organisme gebracht worden, wat voorheen, met klassieke kruisingsmethoden ondenkbaar was.

Dat opende totaal nieuwe perspectieven, niet alleen in de landbouw, maar ook in de voedselindustrie, chemie, farmacie, en milieutechniek. De bespreking van institutionele omgeving was geïntegreerd in de historische beschrijving van de hoofdstukken vier en vijf, maar voor een behandeling van institutionele ontwikkelingen van na 1970 is hoofdstuk acht gereserveerd. Aan de orde komen onder andere de financiering van publiek onderzoek, het onderwijs met betrekking tot beide sectoren, regulering en wetgeving, en overheidsbeleid.

Het historisch overzicht is voorafgegaan door hoofdstuk drie waarin de belangrijkste technologische ontwikkelingen worden besproken om de leek vertrouwd te maken met de technologische geheimen van beide sectoren.

Opvallend is dat de innovaties die zijn voortgebracht door Nederlands telecommunicatie onderzoek, vooral een incrementeel karakter hebben. Doorgaans bouwen ze voort op bestaande concepten, en innovaties bestaan daaruit dat door middel van kleine veranderingen het uiteindelijke resultaat geleidelijk verbetert. Maar dat is niet altijd het geval. Op het gebied van de radiotelegrafie en –telefonie heeft Nederlands onderzoek in de twintiger jaren baanbrekende werk verricht, vooral in lange afstandstransmissie in het lange-golf bereik. De noodzaak om contact te houden met de voormalige koloniën en met de handelsvloot hebben een belangrijke impuls gegeven aan dat onderzoek. Het is trouwens opvallend dat het Nederlandse telecommunicatie onderzoek zich vooral concentreerde op transmissietechniek en veel minder aandacht schonk aan schakelsystemen. Nederland was ook vroeg in het toepassen van grondkabels. Bij de stand van de techniek aan het begin van de twintigste eeuw bood dat veel betere perspectieven dan de traditionele luchtlijnen, die zeer gevoelig waren voor weersinvloeden (zout, ijzel, storm). De specialisatie in transmissietechnologie blijkt een goede zestig jaar later nog steeds, als de Nederlandse PTT als een van de eerste in Europa besluit om over te stappen op digitale signaaloverdracht en daarvoor optische kabels inzet. In de jaren negentig van de vorige eeuw wordt in dit kader nieuwe technieken geïntroduceerd, zoals het aanleggen van uitgebreide netwerken van holle buizen, vooral in de zakencentra rond stedelijke agglomeraties. In dit buizenstelsel wordt dan later, door middel van hoge druk, een optische kabel geblazen. Deze innovatie zorgt er voor dat flexibele netwerken kunnen worden aangelegd, zonder dat iedere keer de straat opengebroken moet worden.

In het algemeen echter is het Nederlandse technologische telecommunicatieonderzoek eerder een volger dan een initiator. Dat geldt echter niet voor het *toepassen* van nieuwe technieken. Nederland was er steeds vroeg bij wanneer nieuwe apparatuur op de markt verscheen en zeker na de liberalisering van de telecommunicatiemarkt ontstond er een breed veld voor nieuwe toepassingen, nieuwe producten en (vooral) nieuwe diensten. Het ontwikkelen van zulke diensten hangt aan de ene kant af van de technische mogelijkheden, maar aan de andere kant ook van de mogelijkheden om nieuwe diensten te implementeren in de bedrijfsomgeving. In dat toepassingsgerichte onderzoek komt het aan op het complexe samenspel tussen technologie en menselijk gedrag.

Het landbouw-, voedingsmiddelen- en chemiecluster (LVC cluster) is buitengewoon innovatief geweest door de jaren heen. De toepassing van kunstmest was een belangrijke innovatie die de productiviteit van de landbouw, maar ook van de voedingsmiddelenindustrie enorm heeft vergroot. Maar het is slechts een voorbeeld. De Nederlandse landbouw had toen al een voorsprong op andere landen. De gemiddelde opbrengst per hectare landbouwgrond was hoger, de gemiddelde melkgift was groter en ook de vleesproductie was hoger. De innovativiteit van de Nederlandse landbouw is een voortdurende combinatie geweest van het toepassen van expliciete kennis zoals die in opleidingen en cursussen wordt onderwezen en de impliciete kennis die verborgen ligt in de handen en hoofden van boeren en tuinders. Vaak leidde dat tot kleine veranderingen en verbeteringen, soms tot grote doorbraken en soms ontstond er een domino-effect, doordat innovaties in het ene veld een reeks van innovaties in andere sectoren teweegbracht.

De ontwikkelingen in de moderne biotechnologie sloten uitstekend aan op het onderzoek dat in het LVC cluster in voorgaande jaren was ontwikkeld. Moderne biotechnologie voegde als het ware nieuwe instrumenten toe aan het reeds bestaande instrumentarium en aanvankelijk waren de toepassingen er op gericht om hetzelfde te doen, maar op een andere manier. Insuline bijvoorbeeld werd tot dan toe gewonnen uit de alvleesklier van dieren, maar het nieuwe instrumentarium stelde biotechnologen in staat om synthetische insuline te bereiden, zonder de bijwerkingen die de oude producten nog kenmerkten. In wasmiddelen werden fosfaten vervangen door enzymen als werkzame stof. Een uitgebreide lijn van onderzoek werd opgezet in gewasverbetering, maar verder dan veldproeven is het nauwelijks gekomen. Maatschappelijke weerstand en veranderde opvattingen ten aanzien van vergunningverlening hebben een belangrijke rem gezet op innovaties in dit laatste veld.

Een belangrijk verschil tussen de telecommunicatie sector en het LVC cluster is dat de eerste vooral opereerde binnen een nationaal perspectief, terwijl het LVC cluster veel meer een internationale, exportgerichte oriëntatie had. Ook wat de organisatorische structuur betreft zijn er belangrijke verschillen. De telecommunicatie-industrie laat zich het best karakteriseren als een assemblage industrie, die zich specialiseert op het samenvoegen van elementen, waarbij ieder element zijn eigen idee-innovatie-keten heeft.. Aanvankelijk werden al deze elementen door een en hetzelfde bedrijf geproduceerd, maar later gingen bedrijven er steeds meer toe over om onderdelen van externe leveranciers te betrekken. Dit proces, waarbij de oorspronkelijke keten zich opdeelt in steeds meer afzonderlijke ketens noemen we verticale differentiatie. Met de technologische omslag van analoge naar digitale systemen is de mate van verticale differentiatie enorm toegenomen in de telecommunicatie-industrie. Ondanks het feit dat het LVC cluster een soortgelijke technologische omslag kent, is daar toch geen sprake van een sterke toename van verticale differentiatie. In het laatste cluster is veeleer sprake van horizontale differentiatie en daarmee wordt geduid op het verschijnsel dat tussen de oorspronkelijke fasen van de idee-innovatie-keten steeds nieuwe fasen worden gevoegd. Het totale traject van idee naar product wordt daarmee vooral langer. De verklaring is dat het LVC cluster veel meer moet worden gezien als een procesindustrie, waarbij één product steeds verschillende bewerkingen ondergaat, die uiteindelijk leiden tot verschillende producten.

Een belangrijk aandeel in de innovatieve prestatie van een land wordt geleverd door innovatieve startende ondernemers (starters), die kleine, hoogdynamische bedrijven op poten zetten. Zulke starters vinden we in beide sectoren, maar als we kijken in welk onderdeel van de idee-innovatie-keten ze actief zijn, zien we een belangrijk verschil. De telecom-starters vinden we vooral aan het eind van de keten, in productie, verkoop en toepassing. In de biotechnologie daarentegen, vinden we starters juist in het begin van de keten, waar fundamenteel onderzoek overgaat in toegepast onderzoek. Bovendien, telecom-starters zijn vooral afkomstig uit de bedrijven zelf, terwijl biotech-starters vooral afkomstig zijn uit de universiteiten en onderzoeksinstellingen.

Hoe meer de idee-innovatie-keten wordt opgeknipt in kleinere onderdelen of afzonderlijke ketens, hoe groter de noodzaak om die onderdelen op elkaar af te stemmen. De telecommunicatiesector vormde wat dat betreft een betrekkelijk overzichtelijk geheel. De diensten werden uitsluitend aangeboden door de PTT in de vorm van een staatsmonopolie. De industrie bestond uit één grote leverancier (Philips in de naoorlogse jaren met een marktaandeel van zeventig procent) en twee kleinere (ieder met een aandeel van vijftien procent). De relatie tussen industrie en PTT was bijzonder hecht en vormde in feite een onderdeel van de gemonopoliseerde structuur die de telecommunicatie-industrie tot in de tachtiger jaren heeft gekenmerkt. Na de liberalisering van de telecommunicatiemarkt is er een belangrijke verandering opgetreden. Nieuwe aanbieders hebben zich op de markt gestort met zowel diensten als producten. Na een stormachtige entree lijkt het aantal aanbieders zich echter te concentreren rond enkele grote spelers, waarin de voormalige nationale aanbieders een relatief sterke stem hebben. Met de liberalisering van de markt is ook het coördinatiemechanisme veranderd. In het verleden werd het sterk gedomineerd door de hiërarchie van zowel industrie als aanbieder. Tegenwoordig vindt coördinatie eerder plaats door markt relaties.

Dat alles staat in schril contrast met het LVC cluster, waar coördinatie traditioneel plaatsvond in netwerken. De grote industriële conglomeraten in de voedingsmiddelenindustrie en de chemie zijn weliswaar te karakteriseren als hiërarchieën, maar ze zijn sterk verbonden met netwerken of vloeien er rechtstreeks uit voort. Veel grote agro-industriële ondernemingen vinden hun oorsprong in de klassieke landbouwcoöperaties, bij uitstek netwerkgerichte bedrijven. Juist in die bijzondere omstandigheid schuilt een deel van de dynamiek van de sector. Landbouwcoöperaties hadden bij uitstek een regionaal karakter, maar het werd in het algemeen ongewenst gevonden dat de technische staf of de directie uit dezelfde regio afkomstig was, omdat dit gemakkelijk tot belangenverstrengeling zou kunnen leiden. Daarom werden directies en stafleden van buiten de regio aangetrokken en dit waren vooral goed opgeleide personen, met flink wat kennis in hun bagage. Een plezierige bijwerking van het tegengaan van belangenverstrengeling was het binnenhalen van kennis en innovatief vermogen.

Instituties verschaffen bronnen en helpen om informatie en gedrag te structuren. Ze bieden stabiliteit in sociale interactiepatronen en verminderen onzekerheid voor personen die beslissingen moeten nemen. Instituties tenderen weliswaar naar duurzaamheid en stabiliteit, maar ze zijn ook flexibel en passen zich aan aan technologische ontwikkelingen. Het ontmantelen van het staatsmonopolie van de PTT in het kader van de liberalisering van de telecommunicatiemarkt kan worden gezien als een institutionele aanpassing aan de technologische omslag van de klassieke analoge systemen naar moderne digitale systemen.

De telecommunicatiesector is heel lang een wat gesloten, naar binnen gekeerde wereld geweest; een technologisch eiland met een gering aantal verbindingen met de omringende wereld. Onderwijs en training vond veelal plaats in de bedrijven. Een gebruikelijke procedure voor jonge telecommunicatie-ingenieurs was bijvoorbeeld om eerst een paar jaar op de research afdeling te werken, alvorens een management- of technische functie elders in de organisatie te aanvaarden. De research afdeling was daarbij een logische aanvulling op het algemeen technische programma van universiteiten en hogescholen. PTT, maar ook Philips hadden grote invloed op het leven van hun werknemers. Veel van het sociale leven was direct gerelateerd aan het bedrijf of het nu ging om de vakantie, de fanfare, het Sinterklaasfeest of de sportclub.

Dat was een duidelijk verschil met het LVC cluster. Zeker de landbouwsector was een complex stelsel van netwerken, en dit werd ondersteund door invloedrijke instituties als de kerk, de politiek, plaatselijke notabelen en de banken. Industrieën in dit cluster, maar ook de grote herenboeren onderhielden nauwe contacten met private en publieke onderzoeksinstituten, verenigingen, branche organisatie en onderwijs. Geen economische sector stond zo open voor de ideeën van de Publieke Bedrijfsorganisatie als juist de landbouwsector. De invloed van dit stelsel van netwerken (of liever nog netwerk van netwerken) heeft ook andere instituties doordrenkt, zoals de het financieel systeem, het kennissysteem en het reguleringsstelsel. Het ontwikkelde bijvoorbeeld regels voor de basiskwaliteit van producten die ter veiling werden aangeboden, maar het was ook aanwezig in het bestuur en de examencommissies van land- en tuinbouwscholen. Opmerkelijk in dit kader is dat het land- en tuinbouwonderwijs in Nederland altijd de verantwoordelijkheid is geweest van het Ministerie van Landbouw en niet van het Ministerie van Onderwijs.

De kenmerkende netwerkstructuur van de landbouw vinden we ook terug in de onderzoeksinstituten. Veel van deze instituten zijn ontstaan omdat coöperaties hun onderzoek en systemen van kwaliteitsbeoordeling onderbrachten in onafhankelijke instituten. Veel landbouwonderzoeksinstituten hebben hun wortels in private financiering, terwijl hun onderzoekstaak eerder een publiek karakter heeft. Het LVC cluster kent ook talloze voorbeelden van privaat/publieke samenwerking. Traditioneel was dat veel minder ontwikkeld in de telecommunicatie sector. Daar was de financiering óf publiek, óf privaat, maar zelden een combinatie. Met de belangrijke technologische veranderingen van de zeventiger en tachtiger jaren is dat overigens veranderd. Onderzoek is nu vaak een onderneming waarin overheid, kennisinstituten en industrie aan bijdragen.

De impact van regulering in de telecommunicatiesector kwam relatief laat op gang in de telecommunicatiesector, maar was wel steeds doordringend aanwezig. De liberalisering van de telecommunicatiemarkt heeft daarin verandering gebracht, maar nog steeds heeft de sector te maken met een reeks van standaarden en internationale afspraken. Bovendien, het openstellen van de markt verloopt geleidelijk, waarbij de overheid ruime bevoegdheden heeft gedelegeerd aan de Onafhankelijke Post en Telecommunicatie Autoriteit om de toetreding van nieuwe aanbieders te waarborgen.

De invloed van regulering op het LVC cluster was traditioneel beperkt, maar is sterk toegenomen tijdens de naoorlogse periode. Nederland is steeds een voorloper geweest, zowel in de landbouw als in de biotechnologie. Veel EU directieven vinden hun oorsprong in Nederlandse wet- en regelgeving.

Als we nu aan het eind van de studie de balans opmaken dan zien we dat de telecommunicatie sector traditioneel wordt gekenmerkt door geringe openheid, een beperkt aantal spelers, weinig verbindingen naar de omliggende wereld. Haar publieke functie is lange tijd veel belangrijker geweest dan haar economisch potentieel en toetreden tot de telecommunicatiemarkt was *de facto* onmogelijk. Het Nederlands telecommunicatieonderzoek heeft zich vooral gespecialiseerd op transmissietechnologie. De technologische veranderingen van de zeventiger en tachtiger jaren hebben echter dit stabiele beeld danig aan het wankelen gebracht. De sector is veel opener geworden en meer aanbieders hebben zich op de markt gestort. Groei was het motto van de jaren negentig en de specialisatie verschoof van transmissietechnologie naar het aanbieden van geavanceerde telecommunicatiediensten. Echter, na de aanvankelijke zuigkracht van de telecommunicatiesector op nieuwe aanbieders, neigt de sector zich te nu te concentreren op die aanbieders die een aanzienlijk marktaandeel hebben kunnen ontwikkelen in de afgelopen jaren.

Het LVC cluster heeft een traditie van openheid, die talrijke actoren met elkaar en met de omringende wereld verbindt. Groei, export en het vergroten van het aandeel op de wereldmarkt zijn de belangrijkste elementen. Maar wat bovendien opvalt in een vergelijk met de telecommunicatiesector is dat de continuïteit van het LVC cluster veel hoger is. De nieuwe instrumenten van het moderne biotechnologieonderzoek konden eenvoudig worden geabsorbeerd in een sector die voortdurend op zoek was naar verbetering. Bovendien, moderne biotechnologie heeft klassieke methoden niet overbodig gemaakt. Het specialisatiepatroon van het LVC cluster is in de basis ongewijzigd gebleven en richt zich vooral op het aanbieden van grote hoeveelheden tegen een lage prijs, waarmee het zich in een middensegment van het internationale aanbod bevindt. Er is echter een tendens naar hogere productkwaliteit en –variëteit, waarmee het zich tracht te positioneren in een hoger segment van de markt.

In het vergelijk tussen de beide sectoren vonden we heel wat verschillen, maar zijn die verschillen voldoende om ons argument te onderbouwen dat innovaties bestudeerd moeten worden vanuit een *nationaal-sectoraal* perspectief? Het lijkt er wel op want het profiel van de beide sectoren past niet in een overkoepelend model dat in gelijke mate geldig is voor de beide sectoren.

Deze studie brengt verschillen in beeld, maar laat tevens zien dat iedere sector op zichzelf een coherent systeem vormt. Het geringe aantal actoren in de telecommunicatie, het geringe aantal verbindingen naar de omringende wereld, de tamelijk gesloten gemeenschap die educatie en training organiseert binnen de bedrijven, wijzen daar allemaal op. Dit alles past in het profiel van het staatsmonopolie dat de PTT was tot 1989. Bovendien, de lineaire organisatie van innovatiegerichte activiteiten past vrijwel naadloos op de hiërarchische organisatie die we zowel bij de industrie als bij de aanbieder(s) aantreffen.

Soortgelijke patronen kunnen we ook herkennen in het LVC cluster. Het omvangrijke netwerkpatroon sluit aan bij de sociale inbedding van de sector in de samenleving, de belangrijke rol van de associaties en andere bedrijfsorganisaties, en het grote aantal spelers in het innovatieproces. Deze resultaten versterken het idee dat samenwerking, verandering, problemen, mogelijkheden en moeilijkheden worden beïnvloed door *sectorspecifieke* patronen. Het is te verwachten dat actoren in het LVC cluster een beroep doen op netwerkrelaties in het geval zich een probleem voordoet, terwijl actoren in de telecommunicatiesector eerder de oplossing zullen zoeken in de hiërarchie van het (eigen) bedrijf. Dat is een hardnekkig patroon dat nauwelijks aan actualiteit heeft ingeboet, ondanks liberalisatie van de sector en het toetreden van nieuwe aanbieders.

Het innovatiesysteem zoals we dat vandaag aantreffen is aan de ene kant het resultaat van de uitdagingen waarvoor het vandaag wordt geplaatst, maar aan de andere kant is het het resultaat van ervaringen uit het verleden en de instituties en organisaties die het verleden heeft voortgebracht. We pakten de draad van de historische analyse op rond 1919 en vonden opmerkelijke stabiliteit van het systeem in beide sectoren. De belangrijkste verandering trad op als gevolg van de technologische verandering van de jaren zeventig en tachtig, maar de impact van deze verandering pakte verschillend uit voor de beide sectoren. Voor de telecommunicatiesector was hij veel groter dan voor de biotechnologie. De verklaring daarvoor is dat de digitalisering de bijl aan de wortels van het analoge stelsel legde, terwijl de veranderingen in de biotechnologie gemakkelijk kon worden geïntegreerd in het reeds gebruikte instrumentarium, zonder daarbij bestaande instrumenten te verdringen.

De structuur van het innovatiesysteem in beide sectoren is in hoge mate doordrenkt door ervaring, padafhankelijkheid en de instituties die ze hebben voortgebracht. Sommige zijn het gevolg van kleine gebeurtenissen in het verleden, andere zijn in beweging gezet door veranderingen in grote technologische systemen, maar in alle gevallen is het lonend gebleken om een specifiek ontwikkelingspad te blijven volgen. Dat kan worden verklaard doordat in er in het begin vaak al hoge kosten zijn gemaakt. Maar ook wanneer dat niet het geval is, is het moeilijk om van een eenmaal ingeslagen ontwikkelingsroute af te wijken, omdat gaandeweg leereffecten ontstaan, waardoor het doorgaan op dezelfde weg steeds lonender wordt. Een ontwikkelingspad heeft de neiging om een eenmaal gekozen richting te versterken en alternatieven af te wijzen. Mensen neigen er vaak toe om bij hun oorspronkelijke keus te blijven en toekomstverwachtingen brengen actoren er toe om hun acties daarop af te stemmen; padafhankelijkheid is een zichzelf onderhoudend systeem dat leidt tot terugkerende, *sectorspecifieke* patronen. Zulke patronen zijn aangetroffen in de techniek. Een systeem om de stabiliteit van het signaal in kabels te stabiliseren (pupiniseren), ingevoerd aan het begin van de twintigste eeuw heeft er (mede) toe geleid dat Nederlandse telecommunicatieproducten niet compatibel waren met die van de buurlanden. De technologische karakteristiek van het telecommunicatienetwerk is tot aan de digitalisering beïnvloed door zo'n relatief onbeduidend besluit. In het LVC cluster is dat merkbaar in de vormgeving van organisaties en instituties. De geschiedenis van de landbouwsector doortrokken van netwerkachtige patronen en misschien is de landbouwcoöperatie wel de belangrijkste innovatie in het cluster. Het bereik en de implicatie van die innovatie kunnen moeilijk worden onderschat. Ze beïnvloedden de regelgeving, het onderwijs, de aanpak van onderzoek, maar ook de financiering er van. De Raiffeisen- en Boerenleenbanken zijn opgezet als coöperaties, maar hun invloed reikte veel verder dan alleen het beschikbaar stellen van geld. De banken speelden een actieve rol in het moderniseringsproces en ontwikkelden zich tot belangrijke spelers in het veelomvattend expertsysteem dat de landbouw heeft gekenmerkt. Daarin is overigens de laatste jaren wel een verandering opgetreden. De overheid trekt zich geleidelijk meer terug en er ontstaat ruimte voor nieuwe financiële arrangementen, zoals bijvoorbeeld zaai- en durfkapitaal. Het moderne biotechnologieonderzoek is deels gefinancierd uit deze nieuwe bronnen

Dat roept onvermijdelijk de vraag op of de natiestaat er nog toe doet in een wereld waar onderzoekers gemakkelijk met elkaar communiceren en informatie uitwisselen door het gebruik van moderne ICT hulpmiddelen en waar productie is verspreid over verschillende landen? Kunnen we nog wel spreken van een nationaal systeem van innovatie als activiteiten dáár worden georganiseerd waar ze het goedkoopst zijn en het minst worden gehinderd door regelgeving. Is er voor landen nog wel een voordeel te behalen? Wij denken van wel. Ieder land dat zijn eigen bronnen en groeipotentieel kent kan daarmee ondersteunende condities creëren. De ontwikkelingslanden hebben dat gedaan met het voordeel van lage lonen, maar ze kunnen dat voordeel alleen behouden als zij kunnen innoveren in productietechnologie. De 'oude' landen hebben traditioneel een sterke positie in speur- en ontwikkelingswerk, want ze kunnen bogen op het cumulatieve effect van kennis en een goed ontwikkeld systeem van kennisproductie en –verspreiding. De meeste westerse landen hebben een institutionele omgeving ontwikkeld met sectorale bronnen die ondersteunend zijn voor innovatie en economische ontwikkeling. De beste resultaten kunnen worden verwacht als kennissystemen, financieringssystemen en reguleringssystemen nauw op elkaar zijn afgestemd en elkaar versterken. De Nederlandse landbouw is een voorbeeld van een sector die in staat is gebleken dit synergetisch voordeel op te bouwen en ten volle te benutten.

Dat leidt ons terug naar de initiële vraag: is het *nationaal-sectoraal systeem van innovatie* een relevant onderzoeksconcept en doet het ertoe? Ons antwoord is bevestigend. Gebaseerd om het materiaal dat we hebben verzameld kunnen we vaststellen dat er systematische verschillen bestaan tussen de beide sectoren. Deze verschillen treden aan het licht in de manier waarop ze omspringen met technologie, hoe ze innovatieve activiteiten organiseren, hoe de institutionele omgeving sectorale bronnen levert aan het innovatiesysteem, en hoe de sectoren vorm geven aan de sociale en economische interacties tussen de actoren.

Ondergraaft het *sectorale* perspectief van het NSSI dan de relevantie van het nationale innovatiesysteem. Wij denken dat dat niet het geval is. Onze *sectorale* benadering is eerder te zien als een aanvulling op de meer algemene noties van de nationale systemen van innovatie benadering, maar onze benadering biedt meer diepte en precisie bij het begrijpen van de mechanismen die innovatieve prestatie van een land verklaren. Een sectoraal perspectief opent bovendien de mogelijkheid dat wetenschaps- en technologiebeleid op maat kan worden gemaakt voor afzonderlijke economische sectoren om daarmee hun innovatieve prestatie te versterken.

Glossary

ABON	Association of Biotechnology Centres
ADSL	Asymetric Digital Subscriber Loop
ADSL	Asynchronous Digital Subscriber Line
APS	Application Service Provider
ARCO	Automatische Relais Calculator voor Optische Berekeningen (Automatic relay Calculator for Optical Calculations)
ARRA	Automatisch Relais Rekenmachine (Automatic Relay Calculator)
ASAM	ATM Access Multiplexer
ASK	Amplitude Shift Keying
AT&T	American Telephone & Telegraph Company
AVEBE	Cooperatieve Verkoop en Productievereniging van Aardappelmeel en Derivaten (Cooperative Sales and Production Association of Starch products and Derivates)
BASF	Bayerische Analin und Soda Fabrik
BISDN	Broadband Integrated Service digital Network
BS	Base Station
BTG	Bond van Telecommunicatie Grootverbruikers (Association of Large-scale Telecom users)
BTMC	Bell Telephone Manufacturing Company
BTS	Base Transceiver Station
CAPT	Consultative Body Postal and Telecommunications
CAPT	Commission for Advice on Postal and Telecommunication Policy
CaTV	Cable for Television connection
CBS	Centraal Bureau voor de Statistiek (Dutch Statistics)
CDMA	Code Division Multiple Access
CODEC	Code/Decode chip
COGEM	Commissie Genetische Modificatie (Advice Committee on Genetical Modification)
CPB	Centraal Plan Bureau (Central Planning Bureau)
DBF	Independent dedicated Biotechnology Firm
DCS	Digital Cellular System
DECT	Digital Enhanced Cordless Telecommunications
DLO	Dienst Landbouwkundig Onderzoek (Agricultural Research Office)
DNL	Dr. Neher Laboratorium
DSL	Digital Subscriber Line
DSM	De Staatsmijnen (The State-Mines)
DWDM	Dense Wave Division Multiplexing
EDFA	Erbium Doped Optical Fibre
EDGE	Enhanced Data Rate for GSM Evolution
EDSAC	Electronic Delay Storage Automatic Calculator
EIR	Equipment Identity Register
ELISCO	Entrepreneurial Life Science Company
ENIAC	Electrical Numerical Integrator and Computer

ENKA	Eerste Nederlandse Kunstzijde Fabriek (First Dutch Art Silk Factory)
ERMES	European Radio Messaging Service
ETM	Ericsson Telefoon Maatschappij
ETSI	European Telecommunication Standards Institute
EU	European Union
EZ	Ministry of Economic Affairs
FOM	Stichting Fundamenteel Onderzoek de Materie (Foundation for Fundamental Research on Matter)
FSK	Frequency Shift Keying
FTP	File Transfer Protocol
GEO	Geo-Stationary Satellites
GERD	Gross Expenditure on R&D
Ghz	Gigahertz
GMO	Genetical Modified Organism
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HDTP	Hoofd Directie Telecommunicatie en Post (Directorate General Telecommunications and Post
HIJSM	Hollandsche Ijzeren Spoorweg Maatschappij (Netherlands Iron Railroad Company)
HKI	Hollandsche Kunstzijde Industrie (Netherlands Rayon Industry)
HLR	Home Location Register
HSCDS	High Speed Circuit Switched Data
ICT	Information and communication technology
IN	Intelligent Network
IOP-b	Innovation Oriented Programme Biotechnology
IP	Internet Protocol
IRC	Internet Relay Chat
ISDN	Integrated Service Digital Network
ISO	International Standards Organisation
ISP	Internet Service Provider
IT	Information technology
ITU	International Telecommunication Union
kbit/s	Kilobyte per second
KPN	Koninklijke PTT Nederland (Royal Dutch PTT)
LEO	Low Earth Orbit Satellites
LMNE	Large Multinational Enterprises
MDF	Main Distribution Framework
MEO	Medium Earth Orbit Satellites
Mhz	Megahertz
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry (Japan)
MS	Mobile Station

MSC	Mobile Switching Centre
MSC	Materials Science Centre
NatLab	Natuurkundig Laboratorium (Philips) (Philips Physics Lab)
NBTM	Nederlandsche Bell Telefoon Maatschappij
LNV	Ministry of Agriculture, Nature Management and Fisheries
NEM	Nederlands Elektriciteits Museum (Netherlands Electricity Museum)
NIABA	Nederlandse Biotechnologie Associatie (Netherlands Biotech Association)
NIOK	Netherlands Centre for Catalysis
NIZO	Nederlands Instituut voor Zuivel Onderzoek (Netherlands Institute for Basic Research)
NKF	Nederlandse Kabel Fabriek (Netherlands Cable Factory)
NORTEL	Northern Telecom
NSEM	Nederlandsche Standaard Elektrische Maatschappij
NSF	Nederlandsche Seintoestellen Fabriek
NSI	National Systems of Innovation
NSSI	National-Sectoral System of Innovation
NTBF	New Technology-Based Firm
NTBS	New Technology-Based Sector
NVP	Nederlandse Vereniging van Participatiemaatschappijen (Netherlands Association of Venture Capital Companies)
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek (Netherlands Organisation for Scientific Research)
OCW	Ministry of Education, Culture and Sciences
OECD	Organisation for Economic Development
OPTA	Independent Post and Telegraph Authority
OSI	Open System Interconnection (architecture)
OVO	Onderzoek, Voorlichting, Onderwijs (Research, Information and Education)
PABX	Private (Automated) Branch Exchange
PASCAL	Philips Akelig Snelle Calculator (Philips Incredibly Fast Calculator)
PBO	Publiekrechtelijke Bedrijfsorganisatie (Statutory Industrial Organisation)
PBX	Private Branch Exchange
PCI	Philips Computer Industry
PETER	Philips Experimentele Tweetallige Electronische Rekenautomaat
PKI	Philips Kommunication Industri (Germany)
PRO	Public Research Organisation
PSDN	Packet Switched Digital Network
PSK	Phase Shift Keying
PTERA	PTT Electronische Reken Automaat (PTT Electric Calculator)
PTI	Philips Telecommunication Industrie
PTT	Post- Telegraph and Telephone Administration
RCI	Relative Contractual Partnering Index

SAN	Storage Area Network
SDH	Synchronous Digital Hierarchy
SDSL	Synchronous Digital Subscriber Line
SIM	Subscriber Identity Module
SME	Small and Medium-sized Enterprises
SPC	Stored Programme Control
SPRU	Science Policy Research Unit
STANTEC	Standard Telephones and Cables
SWOKA	Instituut voor Strategisch Consumentenonderzoek
TKF	Twentsche Kabel Fabriek (Twente Cable Factory)
TLS	Transparent LAN Services
TNO/STB	TNO/Strategie, Technologie en Beleid (TNO, Strategy, Technology and Policy
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
TPC	Transmission Control Protocol
TSER	Targeted Social Economic Research
UIPS	Utrecht Institute for Pharmaceutical Sciences
UMTS	Universal Mobile Telecommunication System
VCNI	Vereniging van de Nederlandsche Chemische Industrie (Association of the Netherlands Chemical Industry)
VLR	Visitors Location Register
VNO-NCW	Vereniging Nederlandse Ondernemingen/Nederlands Christelijk Werkgeversverbond (Association of Netherlands Employers/Industry)
VROM	Ministry of Housing, Spatial Planning and the Environment
V&W	Ministry of Transport, Public Work and Water Management
VWS	Ministry of Public Health, Welfare and Sports
WDM	Wave Division Multiplexing
WEC	Western Electric Company
WLL	Wireless Local Loop
WTO	World Trade Organisation
WWW	World Wide Web
ZEBRA	Zeer Eenvoudige Binaire Reken Automaat (Very Simple Binary Calculator)

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Curriculum Vitae

Herman Oosterwijk was born on January 8th 1953 in Diepenveen. He started his professional career when he was just 18, as an assistant manager in a youth-hostel. From 1971 he had several positions in welfare and community work, and gradually moved towards positions in management and policy development. He received his professional education training part-time, at the Social Academy of Sittard (Intermediate Vocational Education) and subsequently the Social Academy of Hengelo (School of Higher Vocational Education). After several courses related to management and organisation, he studied General Social Sciences (ASW) -again part-time- at Utrecht University, with a specialization in organisation, policy and management. In 1998 he graduated with a thesis on the implementation of government-policy in the case of Islamic ritual slaughtering, by the National Inspection Service for Lifestock and Meat (RVV). From 1999 to 2002 he worked as a researcher in the EU project National Systems of Innovation and Networks in the Idea-innovation Chain in Science-Based Industries, which was a comparative analysis of four countries (Austria, Finland, Germany and the Netherlands) in the case of telecom and biotech.

Herman Oosterwijk is currently holding a position as an assistant-professor at the School of Business, Public Administration & Technology at Twente University