Danish Agency for
Trade and Industry
Ministry of Business and Industry

The Creation, Distribution and Use of Knowledge

- A Pilot Study of the Danish Innovation System

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Foreword

Since a couple of years the OECD-secretariat has co-ordinated studies of national innovation systems with a special emphasis on their capbility to distribute and absorb knowledge. Currently close to a dozen countries including Finland, Norway and Sweden are involved in an activity aiming at mapping the national accesible data sets, which are relevant to illustrate these capabilities.

In 1995 Danish Agency for Trade and Industry (Erhvervsfremme Styrelsen) asked the IKE-group at Department for Business Studies, Aalborg University to take charge of the Danish part of this international project. This report is the outcome of this request. In accordance with the mandate given through the OECD-coordination the main content of the report is a presentation of the empirical foundation of the analysis; what data are accessible in Denmark and for what purposes can they be used? Only to a smaller degree has the potential for analysis of the data sets been carried out (especially this has been done for R&D-data). In this context it should be mentioned that the IKE-group and DRUID (the Danish Research Unit for Industrial Dynamics) has now been asked by the Danish Agency for Trade and Industry to go into a much more ambitious and more analytically oriented effort, which will run over the period 1996-1998. The Disko-project will analyse different dimensions (firm and inter-firm levels as well as structural and institutional aspects) of the Danish Innovation System in a comparative perspective.

Bengt-Åke Lundvall and Björn Johnson have been responsible for organising the OECD-related study. Main author of the report is Keld Laursen, while Jesper Lindgaard Christensen has made important contributions, especially to the sections on the innovation surveys and on the technological infrastructure.

The study has been financed by the Industry and Trade Council (Erhvervsudviklingsrådet), and Britta Vegeberg from the Danish Agency for Trade and Industry has been the contact person in relation to the research group. As the Danish representative in the OECD-working party responsible for the NSI-work, she has also mediated between the research group and the OECD-secretariat.

Aalborg, 23 May 1996

Bengt-Åke Lundvall
Björn Johnson

Executive summary

Historical growth analysis, trade data and labour market statistics all indicate that knowledge is becoming the strategic resource and that learning the most important process in the economy. In order to understand the implications of a dynamic world, where change is the rule, rather than the exception, new tools of analysis have to be developed and further refined, both in terms of the theoretical framework and empirical measurement, but also in terms of the interface between two. One possible tool in this context, is the literature on National Innovation Systems, which will provide the theoretical background for this study.

The study largely follow the work plan for the pilot case studies, outlined by the OECD directorate for Science, Technology and Industry (OECD, 1995). Similar studies are pursued in many other OECD countries. The objective is to carry out a preliminary and empirically based analysis of the Danish Innovation System, especially with regard to the diffusion and utilisation of the knowledge production taking place at universities, research organisations and business firms. A more detailed description of the context of the report is available in chapter 1.

In chapter 2, the theoretical framework is discussed and presented, and it is argued that NIS should be analysed in terms of a sectoral approach, given that innovation is a process which is differentiated across sectors. Furthermore, the definition of the system is narrowed down by focussing on institutions directly involved in the creation and distribution of knowledge in a NIS. Likewise it is pointed out that the focus is on the interactivity of the system, and less on aspects of 'social capability'. In addition five types of knowledge flows are identified, to be used in the empirical chapters (primarily chapter 4). The five flows identified are: Flows embodied in commodities, traded between sectors; flows going through other inter-firm (mainly user-producer) relationships; flows facilitated via university-industry relations; flows facilitated via the interaction between other (other than university) public institutions and business firms; and flows embodied in people (personal mobility).

Chapter 3 describes the Danish business sector in terms of sectoral distribution. In this context some areas of specialisation are identified. An interesting aspect of the Danish system is that an area which is not so well researched, namely services, accounted for more than 25% of total Danish R&D in 1991. What was not so surprising is Denmark's specialisation in food, drink and tobacco; pharmaceuticals; non-electrical machinery; and instruments, and under specialisation in automobiles; aerospace; and information technology, generally.

Such relative strengths and weaknesses are the same whether measured as value added, production, employment or R&D.

Furthermore an attempt is made to asses whether the low R&D intensity in Danish manufacturing industry is caused by a disadvantageous sectoral specialisation. It is shown that this is to some extent the case. However, if firms in a NIS are not able to conduct meaningful technological search in technologically unrelated areas, because of the path dependent nature of technological change, enhanced durable user-producer interaction and so on, it is not meaningful to conclude that Denmark should dramatically change sectoral specialisation because the sectors in which the country is specialised, appear to offer generally low growth in technological opportunity. Given such rigidities, Denmark will not, in the foreseeable future, get a (real) R&D intensity at the *level* of the OECD9. However, this not to say that the Danish system is performing well in terms of R&D performance. It remains a fact that Denmark's R&D intensity is significantly below the OECD9 average. What might be worrying is that not more resources are allocated to R&D in 'medium' or 'low tech.' sectors in Denmark, since more resources should be available for conducting research in these sectors, given that Danish firms in 'high tech.' sectors are using considerably less resources compared to what is used by the same sectors in other countries. This is so since the relative size of these 'high tech.' sectors are smaller in Denmark (except from pharmaceuticals), when compared to the majority of advanced countries. Thus, given that Danish firms are relatively (very) competitive in non-electrical machinery and food, drink & tobacco it is particularly worrying that these sectors are not conducting significantly more R&D pr. value added than do the OECD9. Moreover, it is worrying that Danish firms are generally conducting less R&D in 'low tech.' (> 3.5 R&D intensity), compared to the OECD9, since Danish firms in only three out of ten 'low tech.' sectors are conducting significantly more R&D than does the OECD9 average.

From a dynamic perspective, it is encouraging that Danish firms tends to conduct a larger share of OECD9 R&D in the period 1980 to 1991. However, it should be noted that the gain is not coming from the whole business part of the NIS; the gain is largely due to an increase in R&D expenditures in only three sectors, out of 22 (pharmaceuticals; non-electrical machinery; and instruments).

Chapter 4 looks into the interaction in the Danish NIS, structured according to the types of knowledge flows described in the beginning of this chapter (and discussed in chapter 2). Firstly, various feasible methods of measuring embodied knowledge flows are presented and discussed. Accordingly, such flows can be measured by means of input-output tables on the one hand and ANBERD data, CIS data or IDA labour market data on the other hand.

Secondly, analytical possibilities using CIS and also to a smaller extent PACE data in order to analyse and describe user-producer co-operation and R&D

collaboration, are considered. It is shown that market factors play an important role in this context (and significantly more so than the ‘technology factors’). However, it is stressed that the data say nothing about what is the important factor in *carrying out* the innovation. Concerning research co-operation it is demonstrated that 30 - 60 % (depending on size) of Danish firms, conducting research and development, are involved in some kind of research co-operation. In terms of collaboration with the public research system it is demonstrated that the most important form is the informal contact to public researchers.

Thirdly, a discussion of the impact of formal institutions for promoting the creation and distribution of knowledge is conducted in section 4.7. Concerning science parks it is clear that the Danish parks are small as compared to the parks of other countries, and that they have not (yet) become a major engine for setting up new innovative firms, to the same extent as in other countries. However, it is argued that an assesment of the direct impact from the existence of the science parks should be supplemeted by taking into account: 1) linkages to other firms by firms present in the parks; 2) the ability to keep windows of opportunity open to new fields with an uncertain future. When it comes to the technological service system the system is described, and it is argued that this part of the innovation system is probably more important in Denmark, compared to most OECD countries, given the existence of many SMEs (supplier dominated firms and specialised suppliers). Even though the amount of resources allocated to the system is relatively sparse, the OECD has concluded that the Danish technological service system is adequate, but could be more efficient if internal links, within the system are reinforced.

Fourthly, possible methods for using Danish labour market data, in the context of measuring flows of personal are described. In this context there is a lot of opportunity in using the IDA database, which has until now been used mainly by labour economists.

Finally, four Danish case studies are presented as a means of describing some of the interaction in the NIS. What the case-studies demonstrate is that the knowledge-bases differ significantly, between sectors, both in terms of where the knowledge-base resides and in terms of the relative importance of knowledge-bases between sectors. One conclusion arising out of this is that interactivity in the NIS is important, but that it is an empirical question where the most important knowledge-base actually reside.

List of abbreviations

ANBERD	Analytical Business R&D Database
CIS	Community Innovation Survey
CRTOs	Certified Research and Technology Organisations
IDA	Integreret Database for Arbejdsmarkedforskning (Integrated Database for Labour Market Research)
NIS	National Innovation Systems
OECD9	Canada, Germany, Denmark, France, Great Britain, Italy, Japan and the US
PACE	Policies, Appropriation and Competitiveness in Europe (innovation survey)
RDCA	Research & Development Comparative Advantage
SMEs	Small and Medium sized Enterprises
TICs	Technological Information Centres

1 Introduction

Historical growth analysis, trade data and labour market statistics all indicate that knowledge is becoming the strategic resource and that learning the most important process in the economy. In order to understand the implications of a dynamic world, where change is the rule, rather than the exception, new tools of analysis have to be developed and further refined, both in terms of the theoretical framework and empirical measurement, but also in terms of the interface between two. One possible tool in this context, is the literature on National Innovation Systems, which will provide the theoretical background for this study.

The study will largely follow the work plan for the pilot case studies, outlined by the OECD directorate for Science, Technology and Industry (OECD, 1995). Similar studies are pursued in many other OECD countries. The objective is to carry out a preliminary and empirically based analysis of the Danish Innovation System, especially with regard to the diffusion and utilisation of the knowledge production taking place at universities, research organisations and business firms.

The task of studying a complex phenomena, like knowledge diffusion, is not an easy one. Especially because available statistics tend to focus on flows of (tangible) assets, capital and people, whereas knowledge flows must often be assessed, using indirect measures. Many of the indicators outlined by the OECD are ‘blue-sky indicators’ - i.e. it is not likely that indicators exist, and if they do they are not well defined and therefore not comparable across countries. However, for a national study it can be valuable to map the available data also in relation to these indicators. We are also aware that the indicators do not capture many of the essential parts of the national innovation system on their own, but we think that a wide range of indicators may contribute to an understanding of the dynamics and structure of the system.

The empirical part starts with a detailed description and analysis of the business enterprise part of the system. The part of the study which focus on measurement of interaction in the system aims at mapping a range of empirical indicators, existing as well as possible future ones, in relation to the Danish innovation system. It is the objective of this part of the study to focus on *possibilities* for empirical analysis of some of the issues related to the Danish innovation system, rather than giving an exhaustive account of the entire system. In addition, it is the objective to - where possible - give *examples* of the different types of analysis.

Although the main focus will be on the possibilities of empirical analysis, it is also the ambition to describe the general quality and method of collection of data in some detail. Finally, it is in some instances relevant to give a description of part of the institutional structure of the system. The latter description will be kept at a general level and will, as goes for several other issues treated in this report, extended further in a larger project carried out in 1996-1998 (the DISKO-project).

The report consists of four chapters. Firstly, the theoretical framework will be discussed in chapter 2, in order to arrive at important parts of the system to be measured, and subsequently arrive at, how some of these parts can be measured. Secondly, in chapter 3, the sectoral structure of the system (business enterprise) will be described and analysed in relation to eight other OECD countries, for which R&D data are available, using OECD data on R&D, value added, production and employment. Subsequently, analytical possibilities concerning interaction in the system - illustrated by empirical examples - will be elaborated in chapter 4. Finally, chapter 5 contains conclusions, and suggestions on future work.

2 Theoretical framework

2.1. Introduction

This part of the report describes and discusses the theoretical foundation underlying the theories of national innovation systems. The starting point will be a short discussion of the science-technology interface, as it has been applied in various kind of literature. The last part of the chapter discusses, what should be measured and how it can be measured.

2.2. The science-technology relationship

One indirect effect of Solow's (1956) famous neoclassical growth model, was that technological development had to be conceived as a result of research carried out at universities and other public institutions (without any specific market incentives), given the fact that technological development was exogenously determined. Henceforth, many economists have treated technical change as three distinct and sequential items (cf. Metcalfe, 1987), namely invention, often based on scientific advance; innovation (process and product), the transfer of invention to commercial application; and finally, diffusion, the spread of innovation into the economic environment. However, already early on authors such as de Solla Price (1965) argued that science and technology are very different, in having different natures and purposes, thus making the impact from science to technology not very simple and direct. Furthermore, Rosenberg (1982) has from a historical point of view criticised the idea that science affects technology in a linear fashion. Rather, the link between the two is complex; in some areas the link has been rather strong (e.g. in various chemicals); in other areas it has been non-existing; or sometimes the causation has gone from technology to science, like in the case of the Bessemer converter, where scientific research (metallurgy) was initiated subsequently, in order to understand the properties of the metal already produced, using Bessemer technology.

A particular strand of economics, ‘evolutionary economics’[1], takes into account the complex relationship between science and technology, and assumes that technological development has a major impact on economic performance, such as international competitiveness and economic growth. In evolutionary economics it is recognised that important aspects of technology aremainly specific and tacit in nature, since it is - to a large extent - embodied in persons and in institutions, in addition to being cumulative over time (Dosi, 1988, p. 225). Given such a set of assumptions, firms produce things that are technically different from what other firms produce, on the basis of in-house technology, but with some contributions from other firms and from public institutions and public knowledge. In this model, firms are not likely to improve their technology, by making a survey of the complete stock of knowledge, before making technical choices. Rather, given the differentiated nature of technology, firms will try to improve and diversify their technology, by searching in zones that enable them to build on the firms existing technology base. Thus, technological and organisational change is a cumulative process, constraining firms in the possibilities of what they can do, by what they have done in the past (i.e. path dependency). When such a perception of technology is recognised, its development, over time, ceases to be random, but is constrained by the set of existing activities (ibid).

Building on this kind of literature the theorising on national innovation systems has emerged as an attempt to explain apparent differences in technological performance across *nation states*.

2.3. National innovation systems

This section describes the national innovation system approach, to the understanding of the determinants of the rate and direction of technological change. However, since the national innovation system approach is not one single theory, because different authors have had different approaches, it is useful to map some differences and similarities between the approaches.

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[1] As broadly phrased by Freeman (1982), Nelson and Winter (1982), Dosi (1982) and Dosi *et al.* (1988).

Some theoreticians use the term as interchangeable with a country's formal (narrow) R&D system, assuming a linear relationship going from science to technology and further on to economic growth (Mckelvey, 1991). Christopher Freeman has been closer to the approach this study will adopt and put the focus on the organisation of the institutions of the national innovation system. In Freeman (1988), the focus is on the NIS of Japan, particularly the role and organisation of (i) government policy; (ii) the business sectors; and (iii) education, training, and related social innovation. Another early contribution has come from Richard Nelson (1988), where he describes some of the salient features of the US innovation system, by focusing on the formal R&D institutions, including R&D co-operation, the role of universities and government support programmes for R&D. Nonetheless, in setting up the general framework for his now well-known book (Nelson and Rosenberg, 1993), which compares the innovation system of 15 among capitalist countries, he (and Nathan Rosenberg) takes a broader view of the national innovation system, in focusing on:

- the allocation of R&D activities;
- the characteristics of firms and the important industries;
- the role of universities;
- government policy that mould and spur industrial innovation.

However - and as stressed by Nelson and Rosenberg - the broad framework was set up to make empirical similarities and differences between the systems of the different countries involved workable. Partly grounded in the nature of the research project, the Nelson/Rosenberg chapter does not contain an attempt to construct a coherent theory of national innovation systems. Another interesting contribution has come from Porter (1990), in his comprehensive attempt to answer the questions of why a nation becomes the home base for successful international competitors, or why one nation often has become the home for so many of the leading firms of one specific industry. In conducting his analysis, Porter applies four determinants of national advantage, namely; factor conditions, demand conditions, related and supporting industries, and finally, firm strategy, structure and rivalry. A salient feature of Porters analysis is that it focuses on a broad set of factors, rather than solely focussing on 'narrow' R&D activity. However, the approach has been target of criticism, emphasising that the connections between the level of the industry and the level of the nation is unclear, when Porter draws his conclusions (Dalum, 1992).

2.4. Interactive processes as a basis for NIS

A more comprehensive theoretical approach is taken by Lundvall (1992), in trying to provide a new understanding of *innovation as an interactive process* involving many different agents in co-operation and emphasising the fact that the *innovative capability* of a national economy is *rooted in a structured and institutionalised system* and not only reflecting the innovative capability of the individual firms.

A system is constituted by a number of elements and by the relationship between these elements. Thus a national system of innovation can be broadly defined as:

> ... constituted by elements and relationships which interact in production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships either located within or rooted inside the borders of a nation state (Lundvall, 1992, p.2).

Partly building upon the idea, originally put forward by Linder of the (national) home market as an inducer and a 'kinder garden' for new products, Bengt-Åke Lundvall and his colleagues in Aalborg have advanced a theory of user-producer relationships as a stimulus to technological innovation, which in turn is regarded as the micro foundation of the 'National Systems of Innovation'. The basic idea is that of the *organised market,* which involves close, and sometimes face-to-face interaction between sellers and buyers as a fertile environment for innovation, in contrast to the anonymous relationship between agents, assumed in standard economic theory. The interaction may take the form of mutual exchange of information, but may also involve direct co-operation between user and producers of technology. Two properties of the user-producer relationship are important in a national system of innovation context. First, because it is time-consuming and costly to develop efficient channels of communication and codes of conduct (often tacit) between users and producers, the relationships are likely to be durable and selective (Lundvall, 1988, p. 355). Secondly, when technology is sophisticated and changing rapidly, proximity in terms of space and culture is conducive to innovation and thereby to competitiveness.

However, even though the concept of user-producer interaction has been developed mainly in order to understand the interaction in a national system between users and producers of capital goods, the idea of an interactive system is applicable still, in a broader context, and by a broader set of institutional players, even though the interaction might take different forms compared to the interactive learning between users and suppliers. Other relationships might be some kind of interaction between the national science system and the pharmaceutical sector in a country, or it might be small firms interaction with and dependence upon a technological service system.

An important contribution of the broad innovation system approach is that it pays explicit attention to various *institutions* and to the links amongst them, in the promovation of the creation, distribution and use of knowledge in the economy. The basic idea is that markets are only ‘the top of the iceberg’, so that advanced economies need a whole series of underlying institutions *before* markets can function. Such an approach is especially needed in a policy context, in order to avoid narrow-minded policies focusing solely on the functioning of markets. A more specific contribution of the approach advanced by Lundvall (1992) is the explicit focus on the fact that innovation is not only related to technical advances made by means of formal research and development activities, but also takes place in close relation - and interaction with - ordinary production processes. In this context learning processes plays an important part, as described above. It should be noted that the type of learning described by e.g. Lundvall or e.g. Patel& Pavitt (1994), is learning in a broad sense. Neoclassical economists like Arrow (1962) use the concept in a more narrow sense, in dealing with optimisation of a set of *given* resources. Learning in the broad sense also include the creation of truly *new* resources. In other words, the latter concept of learning includes ‘engineering’ trial-and-error and experimentation with new things, whereas the former is more like ‘we get better at doing (producing) it, day by day’. It should also be pointed out, that the famous ‘Arrowian’ learning-by-doing is a function of accumulated gross investment, thus being a mere by-product of production. Thereby, learning get the properties of becoming automatic (what is basically needed is an amount of ‘doing’) and virtually costless (no explicit measures have to be taken in order to capture the benefits from learning). But even though both the NIS and the Arrow approaches focus on learning in conjunction with production, the core of the NIS approach is that ‘learning’ (in both the narrow and broad sense) is costly and requires explicit attention; in other words, the amount and economic usefulness of learning will depend on what is done and on how its done.

Another contribution from the NIS approach has been that it helps to explain persistent (rigid) specialisation patterns among advanced countries in terms of both trade and technology, given the importance of national knowledge bases as a basis for international specialisation and competitiveness. However, it should be stressed that this report follows the overall OECD framework (OECD, 1995, Smith, 1995) and takes a somewhat more restricted approach in focussing on a learning system for scientific and technological knowledge, and excludes some (probably important) related factors, affecting the innovation performance of countries, such as for instance the financial system and the system of management. Thus, this study will focus on three formal knowledge producing entities, namely private firms, universities and the technological service system. Different types of interaction between these entities, taking the form of user-producer relationships, co-operation between rivals, university-industry relations (illustrated by science parks), or the interaction between the technological service system and industry, will be dealth with. Another delimitation of this project is that it is confined to a description of the system and its strengths and weaknesses and the interactivity in various parts of the system. What is not covered to any major extent is ‘social capability’ (Abramowitz, 1986), which can be described as the level of education and the institutions created for the purpose of absorbing knowledge diffused internationally.

An emphasis of the OECD framework is the concept of the ‘distribution power’ of a NIS (see also David and Foray, 1995), i.e. a special focus on how knowledge is diffused and used, rather than just created. However, it should be kept in mind that the distinction between the creation and the distribution of knowledge is mainly analytical. In reality, in advanced countries the application of old knowledge is often closely connected to the creation of new knowledge (Cohen and Levinthal, 1989). One reason for this is that firms conduct R&D in order to understand the results of R&D, conducted by other firms. In other words, firms have to take part in knowledge creation, in order to capture the benefits from the ‘distribution’ of knowledge, produced elsewhere. An interesting property of interactive learning such as user-producer relationships is that this process not only generates new knowledge, but also serves a very important role when it comes to diffusing knowledge through the vertical value adding chain.

Even though a national innovation system consists of more than the sum of its (industrial) sectors, it can be helpful in structuring an analysis, to introduce sectoral differences in a national innovation system context, given that the sources of innovation differ substantially across sectors. The sectoral approach might also be useful in identifying ‘nodal points’ (OECD, 1995) which we will call the knowledge bases in the Danish national innovation system. The sectoral differences is furthermore to be kept in mind, when looking at aggregate indicators of knowledge intensity such as formal research and development in different national innovation systems (section 3.6).

2.5. Knowledge bases in a national innovation system

In trying, more generally, to identify where knowledge bases can reside in national innovation systems, it might be a good idea to take a closer look at what innovation theory has to say about the sources of innovation. One starting point can be von Hippel’s (1988) functional distinction, between the contribution of manufactures, suppliers, and users, to the process of innovation. These functional distinctions fits in with Pavitt’s sectoral taxonomy (1984), which identifies

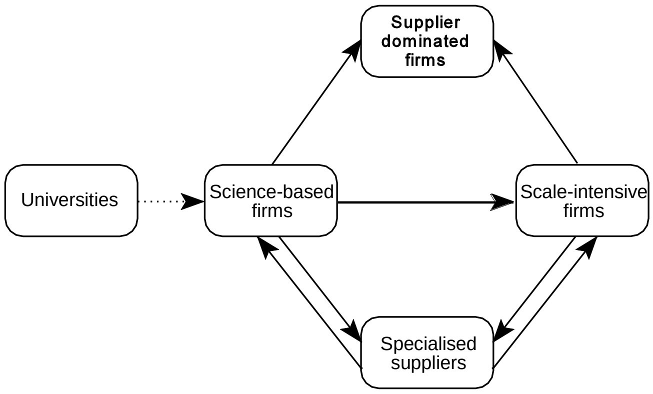

Figure 1: The main technological linkages amongst different categories of firms and universities (cf. Pavitt, 1984, p. 364).

differences in the importance of different sources of innovation according to which broad sector the individual firm belongs to. The taxonomy of firms, according to principal activity, and explained by the sources of technology; the nature of users needs; and means of appropriation, emerged out of a statistical analysis of more than 2000 postwar innovations in Britain. Four types of firms were identified accordingly, namely supplier dominated firms, scale-intensive firms, specialised suppliers and science-based firms. *Supplier dominated* firms are typically small and are found in manufacturing and non-manufacturing sectors. Most technology comes from suppliers of equipment and material (see figure 1, for a description of the main external technological sources of different types of firms). *Scale intensive* firms are found in bulk materials and assembly. Their internal sources of technology are production engineering and R&D departments. External sources of technology include mainly interactive learning with specialised suppliers, but also inputs from science-based firms are of some importance. *Specialised suppliers* are small firms, which produce production equipment and control instrumentation. Their main internal sources are design and development. External sources are users (science-based and scale-intensive firms). *Science-based firms* are found in the chemical and electronic sectors. Their main sources of technology are internal R&D and production engineering. Important external sources of technology include universities, but also specialised suppliers.

The relative importance of process technology is largest among supplier dominated firms and scale intensive firms, while the relative importance of product innovation is larger among specialised suppliers. In science-based firms, the balance between process and product innovation is mixed.

The national innovation system context, knowledge-bases (sources of innovation) can generally be found among the *manufacturers*, but also, however, to a much smaller extent in the *co-operation between rivals* (see von Hippel, 1988, chap. 6), based on complementary assets. Nevertheless, there are also knowledge-bases which are specific to the type of firms in question, according to which broad sector the firms belong. Thus, for scale intensive and specialised suppliers *direct co-operation* between users and producers is of central importance, while interaction with *university activities* are of course of much larger importance of the science-based firms. Likewise, a *technological service system* is probably important for firms in supplier dominated and in specialised supplier dominated sectors, since these types of firms are small, often with a limited amount of individual financial resources.

One important point in this context is that it is possible to say something about the relative importance of the sources of innovation in general - e.g. at the level of users and/or producers - but that it is an empirical question, where important parts of the specific knowledge-base reside. Thus, the high level of Danish competitiveness in hearing aids can be partly explained by interactive linkages to a highly sophisticated domestic public sector, while the strength of the Danish food and drink sectors may partly reside in the interaction with producers of capital equipment for this sector.

2.6. Measurement

This section is an attempt to bridge the gap between the theoretical framework, discussed above, and different empirical indicators, and in doing so to discuss what different variables (i.e. indicators) measure, with a special focus on the measurement of the 'distribution power' of national innovation systems. However, the section will not give detailed descriptions of the methods to be applied[2], but will rather discuss in what way the available data can be applied, to measure the creation and distribution of knowledge in the Danish national innovation system. At the same time the section gives an outline of the subsequent empirical chapter. The 'distribution power' of an innovation system can be characterised by the

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[2] Such a description will be given in chapter 3 and 4, in the context of the empirical analysis, or alternative discussion of how the empirical analysis could be conducted, if more research resources were employed.

following four families of indicators, according the OECD framework (1995, p. 5):

1. indicators of the stock of knowledge;
2. indicators of knowledge flows in the form of knowledge sharing and transfer;
3. indicators of the effectiveness of knowledge sharing and transfer;
4. indicators of the economic impact of knowledge sharing and transfer.

This report will deal with the first two ‘families’ of indicators mainly, and leave the latter two areas for future research. Some attempts to compare and assess different national innovation systems have been conducted, based on either more or less heterogeneous case-studies (Nelson and Rosenberg, 1993) or on available patent and bibliometric statistics (Patel and Pavitt, 1993, Patel and Pavitt, 1994). In this vain this study will start off, by applying OECD data from the Structural Analysis Database (STAN) and the Analytical Business R&D Database (ANBERD), as a means of describing the Danish innovation system in order to deal with point one above. However, it has to be pointed out that R&D data (imperfectly) reflects knowledge creation, as well as the ‘distribution power’ of a national system, and vice-versa that a strong ‘distribution power’ of a system is probably very important for the success of creating new knowledge.

Furthermore, in relation to point one, key questions are - given that Denmark had an R&D intensity of only 45% of the OECD9 aggregate in 1991[3]- in the context of the description of the system are; ‘to which extent can the low R&D intensity be explained by the sectoral composition of the system?’; and in continuation hereof; ‘is Denmark getting access to the sectors associated with the fastest-growing technological development?’

When it comes to knowledge *flows*, more generally (point two above), between knowledge-producing entities, such flows can take the several forms (see Smith, 1995):

- flows embodied in commodities, traded between sectors
- flows going through other inter-firm (mainly user-producer) relationships
- flows facilitated via university-industry relations
- flows facilitated via the interaction between other (other than university) public institutions and business firms
- flows embodied in people (personal mobility)

Such a taxonomy of knowledge flows is consistent with the sectoral framework

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[3] See section 3.6 below.

presented above, where the technological linkages between the four manufacturing sectors can take the form of commodity flows or direct knowledge exchange, mainly upstream-downstream, although personal mobility might be perceived as a main carrier of knowledge *within* the same sector, since knowledge flows embodied in persons might be important for acquiring competences from competing firms, given that knowledge is to a large extent person embodied. The flows also correspond to potential ‘nodal points’ described in the OECD framework (OECD, 1995); in other words important intersections between entities producing knowledge in national innovation systems.

Knowledge flows embodied in commodities (see section 4.3 below), can be measured by means of a combination of ANBERD (or alternatively the innovation surveys) and input-output data. One way of looking at the results of such analysis is to interpret R&D conducted in upstream branches as creating spillovers to downstream industries, since the R&D conducted in the upstream sector - once payed for - will not diminish the returns gained by additional users. Thus, in that case, one can identify an externality. However, given the perception of technology, outlined above, this type of flow and its measurement is better viewed as indicators of the relative intensity of embodied knowledge interactions between various types of industries (Smith, 1995, p. 90).

As concerns knowledge *flows embodied in user-producer relationships* this can be measured by the use of the Community Innovation Survey (CIS), by means of which the importance of different external sources of innovation can be assessed. In addition, the flow of knowledge between sectors can be measured by means of Danish CIS data, via ‘input-output’ type tables, illustrating which sectors co-operate in the innovation process (section 4.4).

When it comes to measurement of flows via *university-industry relationships*, in terms of science parks (sub-section 4.6.1) there is no quantitative data available in the Danish case. Thus, one has to rely on qualitative methods. The same, largely goes for *other public institutions* (sub-section 4.6.2.), mainly consisting of a technological service system, even though some information is available via CIS data.

When it comes to *personal mobility* between sectors, and between universities and different kinds of sectors (section 4.7), this can be measured via the Danish labour market database *IDA*, which is a large database containing information on individual employees, their training and mobility. Given the perception of technology being to a large extent tacit, knowledge flows, via the labour market, is likely to play an important role in the distribution of knowledge in national systems, given the relatively low levels of personal mobility across national borders.

3 Description of the production system

3.1. Introduction

This section will describe to which extent Denmark is specialised and structured in terms of production and in value added, and employment, but will primarily focus on R&D at the sectoral level (22 ISIC sectors). This will be done in order to describe point one in the OECD framework (1995, p. 5), namely indicators of the stock of knowledge. The stock of knowledge can be analysed in a number of dimensions. Two such dimesions are the stock of knowledge compared to other countries at a sectoral level. Another is the change in the stock of knowledge over time. In this regard the section will attempt to answer two key questions - given that Denmark had an R&D intensity of only 45% of the OECD9 aggregate in 1991 - namely; 'to which extent can the low R&D intensity be explained by the sectoral composition of the system?'; and in continuation hereof; 'is Denmark getting access to the sectors associated with the fastest-growing technological development?'. Since, data are available for nine countries only, concerning the sectoral distribution of R&D, all international comparisons will include these nine countries.

The focus in this chapter will be on the manufacturing part of the NIS mainly, as it is in the manufacturing sector Denmark differ markedly from other countries in terms expenditure on R&D. In terms of public expenditure on R&D Denmark is largely similar to other advanced countries. Thus, Denmark spend 0.67 of GDP on R&D at public institutions (1989) - exactly the same amount as the average of the EU countries spend (OECD, 1993). However, when it comes to *interaction* with the manufacturing sector, the Danish system might differ from other countries (to be analysed in chapter 4).

The Structural Analysis database (STAN) has been developed by the OECD and is unique in containing comparable employment variables, import- and export figures, investment, production, and value added for a group of 20 OECD countries at a sectoral level (22 sectors) in the period 1970-1993.[4] The database is an estimated database, building upon a variety of existing databases. The Analytical Business R&D Database (ANBERD), also published by the OECD, is compatible with the STAN database at the sectoral level, although available only for a limited number of OECD countries. The ANBERD data is available for Canada, Germany, Denmark France, Great Britain, Italy, Japan and the US from 1973-1991. In addition, ANBERD includes data on 6 service sectors. The availability of data in these fields is, however, quite scattered and it makes international comparisons problematic. In both bases are data given in local currency, but can be made compatible by a set of exchange rates and equivalent PPPs (purchasing power parities). The OECD study has to do with innovation and knowledge, which in turn make the OECD databases - and ANBERD in particular - an important source of information.

As a starting point the structure of production of the Danish national system of innovation will be described, in terms of value added, production values and employment. Secondly, the distribution and specialisation in doing R&D will be described. Thirdly, and in continuation of the latter, formal R&D in service sectors will be briefly described. Fourthly, R&D intensities at the aggregate level of manufacturing will be presented and discussed, and an attempt to estimate the role of the sectoral composition of sectors in influencing aggregate R&D spending, will be made. Fiftly, the aggregate R&D intensities will be decomposed into sectors, and comparisons of Denmark versus the OECD9 will be made, in addition to a presentation of the development of R&D intensities, in the Danish system, over time. Finally, the chapter will analyse the extent to which the Danish innovation system has been getting access to sectors with high growth in terms of R&D expenditure from 1980 to 1991.

3.2. Value added, production and employment

This section is going to describe the relative economic (direct) importance of the different sectors in the Danish national innovation system. Figures on value added

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[4] It should be noted that not all variables are available for all countries in all time periods.

Table 1: Distribution of value added, production and employment as a percentage of total Danish manufacturing (1973-1991).

			Value added*		Value added		Production	Employment			
			Denmark							OECD9	
No	Sector		1973	1991	1980	1991	1991	1973	1989	1973	1989
1	Food, drink and tobacco	(SDOM)	25.11	24.26	22.34	20.63	28.52	18.39	17.46	8.82	8.52
2	Textiles, footwear and leather	(SDOM)	8.87	5.49	6.16	4.66	4.71	11.30	6.83	13.40	9.93
3	Wood, cork and furniture	(SDOM)	6.70	6.62	4.74	5.63	5.44	7.48	7.19	6.59	6.94
4	Paper and printing	(SDOM)	12.39	12.85	10.85	10.93	9.89	9.88	10.25	8.80	11.58
5	Industrial chemicals	(SCIB)	5.17	6.28	4.66	5.34	4.97	3.41	3.79	4.26	4.00
6	Pharmaceuticals	(SCIB)	1.81	3.81	1.83	3.24	2.20	0.84	1.62	0.76	1.05
7	Petroleum refineries	(SCAI)	1.70	1.51	2.77	1.28	4.16	0.33	0.42	0.74	0.64
8	Rubber and plastics	(SCAI)	2.86	4.37	2.81	3.71	2.69	2.79	3.59	3.67	5.06
9	Stone, clay and glass	(SCAI)	8.64	5.23	5.37	4.45	3.42	6.15	4.23	3.48	2.97
10	Ferrous metals	(SCAI)	1.57	1.11	0.97	0.94	0.76	1.14	0.81	4.67	2.46
11	Non-ferrous metals	(SCAI)	0.50	0.40	0.49	0.34	0.36	0.48	0.39	1.63	1.47
12	Fabricated metal products	(SPES)	7.82	10.06	7.30	8.55	7.43	7.77	9.36	8.15	7.31
13	Non-electrical machinery	(SPES)	-	-	14.62	14.25	11.34	12.31	16.26	9.29	9.04
14	Office machines and computers	(SCIB)	-	-	0.46	0.72	0.40	0.28	0.44	1.14	1.63
15	Electrical machinery	(SPES)	4.85	3.40	3.32	2.89	2.53	5.17	4.31	4.82	6.30
16	Commu. eq. and semiconductors	(SCIB)	2.02	3.31	2.38	2.82	2.40	2.06	2.76	5.02	4.69
17	Shipbuilding	(SCAI)	4.99	3.58	3.50	3.04	3.30	4.98	3.17	0.98	0.98
18	Other transport	(SCAI)	1.21	1.71	1.48	1.45	1.72	1.43	1.78	0.38	0.19
19	Motor vehicles	(SCAI)	0.00	0.00	0.00	0.00	0	0	0	5.11	4.96
20	Aerospace	(SCAI)	0.00	0.00	0.00	0.00	0	0	0	3.16	4.49
21	Instruments	(SPES)	1.83	3.00	2.09	2.55	1.84	1.76	2.93	2.82	3.52
22	Other manufacturing industries		1.96	3.02	1.86	2.56	1.93	2.06	2.40	2.31	2.26

*) excl. sectors 13-14. Source: STAN/OECD

in all sectors, are available from 1980 onwards only.[5] In table 1 the sectors are listed according to the placement in the ISIC nomenclature. Column two is a rough classification into the four Pavitt sectors[6], namely supplier dominated sectors (SUPD); scale intensive sectors (SCAI); specialised suppliers (SPES); and science-based sectors (SCIB). A notable feature is the importance of supplier dominated sectors in the Danish NIS, with sectors 1-4 and 9 adding up to more than 45% of total value added, in 1991. These sectors are dominating, in Denmark, when compared to the OECD9 average, were these sectors added up to less than 35 per cent (see appendix A1). Also, some sectors consisting of specialised supplier firms mainly, are rather large, in the Danish context, such as fabricated metal products (8.55%) and non-electrical machinery (14.25%). In terms of rates of change, pharmaceuticals has been the fastest growing Danish sector (77%), but also sectors like rubber and plastics (32%) and instruments (22%) have been gaining in relative importance. In addition, office machines and computers has been growing rapidly, but from a very small base. If one take a look on production values, rather than value added, the pattern is the same, even though - in relation to the figures on value added - the numbers on production demonstrate that some sectors are quite heavily dependent on physical inputs from outside. As expected, this is the case in food, drink and tobacco and in petroleum refineries.

In terms of employment the supplier dominated sectors remain important (add up to 45% in 1989), but have decreased by 13 per cent as a fraction of employment between 1973 and 1989. Especially remarkable is the fall in employment in textiles, footwear and leather. Likewise, the importance of the specialised supplier sectors like fabricated metal products, electrical- and non-electrical machinery for employment, is noteworthy in the Danish case (add up to about 30% in 1989), rising from being 25% of total employment, in manufacturing.

When compared to the OECD9, it turns out that Denmark was heavily specialised in food, drink and tobacco and in non-electrical machinery, in addition to being specialised in pharmaceuticals; stone, clay and glass; and shipbuilding in 1989. Areas of specialisation below the average in terms of employment, include information technology sectors (sectors 14 &16), in addition to motor vehicles and aerospace, where no significant employment is recorded for Denmark.

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[5] From 1970-1979 non-electrical machinery and office machines and computers have got missing values.

[6] It should be noted that the division of the sectors, according to the Pavitt taxonomy, follows Amable & Verspagen (1995), and the division is therefore not strictly comparable with the distinction, used by e.g. the Ministry of Industry (1995).

3.3. Formal research and development in Denmark

It should be kept in mind that one of the draw-backs of R&D data is that only *formal* research & development is included as R&D in the statistics. Thus, only firms with a formal R&D department are registered as doing R&D in the formal sense. Therefore, R&D figures are likely to underestimate the total effects of technological development undertaken by small firms. Given that firms differ in terms of size and source of technological progress, according to in which sector they operate (Pavitt, 1984), firms in some sectors are much less (formal) R&D intensive, when compared to firms in other sectors. Accordingly, some countries might do less formal R&D, given the composition of the sectors within the country, without it necessarily being implied that the level of technological activity is low. Given these observations one should be careful when comparing countries in terms of aggregate R&D. In section 3.6 below an attempt to overcome some of the difficulties in comparing R&D spending at the aggregate level, will be made. However, for now, it is worthwhile to look at the *relative* specialisation of countries in terms of formal R&D.

3.4. R&D specialisation

Because R&D[7] data is available for nine OECD countries, it is possible to calculate in which sectors Denmark is relatively specialised, compared to the sum of the nine OECD countries. Such a calculation can be conducted be means of the ‘Research & Development Comparative Advantage’, which is the equivalent to the RCA (Revealed Comparative Advantage) well known from the empirical literature on trade (so-called Ballassa indices).

The RDCA index is given as the share of a given sector out of the total R&D conducted by a country, divided by the share of R&D in that sector, out of the total OECD9 R&D. Thus, if the index takes a value above one, a country is specialised in that sector, compared to the rest of OECD9; and if the index is below one, a country is under specialised in that sector. The RDCA index can be described as:

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[7] It should be noted that R&D expenditure in ‘low tech.’ sectors is not as good an indicator of knowledge intensity, as this indicator is in ‘high tech.’ sectors, given that other factors (e.g. an efficient distribution system, specific monitoring etc.) are likely to be more important for competitiveness in these sectors than is formal R&D.

$$RDCA_{ij} = \frac{X_{ij}/\sum_{i} X_{ij}}{\sum_{j} X_{ij}/\sum_{i}\sum_{j} X_{ij}}, \qquad (1)$$

where X_{ij} is R&D in sector i, conducted by country j.

It can be seen from the table below that Denmark does relatively more R&D in food, drink and tobacco, which is not so surprising, given the existence of the ‘Danish agricultural complex/ development block’ (Andersen, 1981; Lundvall, 1984). But also a relative strength can be identified in pharmaceuticals. This finding is also in accordance with trade statistics (Laursen, 1995) and patent statistics (used an indicator of ‘technological activity’)(Patel and Pavitt, 1991). In this context, the existence of a strong Danish science-base should be touched upon, as the science-base provide a strong incentive for technological development in science-based sectors, such as pharmaceuticals. Other relative strengths include wood, cork and furniture; stone clay and glass; non-electrical machinery; shipbuilding[8]; instruments; and other manufacturing. In the latter case one can speculate that the large comparative strength - at least partially- has to do with R&D carried out at Lego, given the fact that toys are included in this sector.

Also worth noting is Denmark’s relative weaknesses in different sectors. In the areas of petroleum refineries; motor vehicles; and aerospace, no significant formal R&D is conducted, which in turn give rise to a RDCA value of 0. Two other areas of relative weakness include sectors related most closely to information technology, namely office machines and computers and communication equipment and semiconductors.

From a dynamic perspective, sectors where Denmark is becoming less specialised include ‘low tech. sectors’ such as wood, cork and furniture; stone, clay and glass; but also a substantial fall in specialisation in a ‘high. tech.’ sector like office machines and computers. In the period in question significant and increasing Danish specialisation appears to have taken place in metals generally; other transport; and in other manufacturing. But also to some extent an increasing specialisation in sectors where the firms could be termed *specialised suppliers*, such as instruments and non-electrical machinery, can be observed. However, the overall picture is one of a remarkable stability in terms of sectoral R&D specialisation between 1973 and 1990. That is, if Denmark were specialised/not specialised, R&D wise, in a sector in 1973, Denmark is likely to be specialised/ not specialised 17 years later, thus confirming the path-dependent nature of technological development, also at the national level (see e.g. Dosi, 1988, pp.

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[8] It should be noted that the US conduct no significant R&D in shipbuilding. Thus, given the amount of US R&D expenditure, nearly all other countries are found to be specialised in shipbuilding.

Table 2: Danish revealed comparative advantage in R&D (RDCA), and distribution of R&D per manufacturing sector (1973-1989).

		RDCA		R&D dist.	
No.	Sector	1973	1991	1973	1991
1	Food, drink and tobacco	3.86	3.98	6.48	6.99
2	Textiles, footwear and leather	0.66	1.08	0.52	0.49
3	Wood, cork and furniture	2.08	1.59	0.55	0.36
4	Paper and printing	0.48	0.82	0.49	0.62
5	Industrial chemicals	0.83	0.48	8.17	4.50
6	Pharmaceuticals	3.96	3.42	18.03	23.79
7	Petroleum refineries	0	0	0	0
8	Rubber and plastics	0.63	0.74	1.39	1.07
9	Stone, clay and glass	2.80	1.66	3.39	2.10
10	Ferrous metals	0.13	0.61	0.21	0.73
11	Non-ferrous metals	0.36	0.84	0.32	0.73
12	Fabricated metal products	1.21	1.62	1.58	1.98
13	Non-electrical machinery	2.14	2.78	12.01	15.60
14	Office machines and computers	0.70	0.29	4.44	2.83
15	Electrical machinery	0.67	0.93	6.12	4.67
16	Commu. eq. and semiconductors	0.82	0.56	12.59	9.90
17	Shipbuilding	26.54	27.22	8.31	2.55
18	Other transport	0.92	3.14	0.32	1.26
19	Motor vehicles	0	0	0	0
20	Aerospace	0	0	0	0
21	Instruments	2.12	2.61	7.65	11.55
22	Other manufacturing industries	10.07	16.20	7.42	8.30

Source: OECD/ANBERD

227-228); in other words, the specialisation in R&D, changes only very slowly.

A striking feature, emerging out of table 2 above, is the difference between the specialisation in R&D, and the distribution of the R&D spending among the 22 sectors. While the specialisation figures are based on an international comparison, the distribution - of course - concerns Denmark alone. Thus, even though Denmark, in 1991, did perform almost 10 per cent of its R&D in communication equipment and semiconductors, Denmark remained heavily under specialised in this particular sector. Likewise did Denmark, in 1991, conduct just about 2.5% of her R&D in shipbuilding, but was very heavily specialised in this sector, with a

RDCA value of more than 27. Such observations, reflect both the difference in the propensity to conduct R&D across industrial sectors and diferences in the size of sectors.

3.5. Research and development in service sectors

As mentioned above, in the description of the databases, the availability of data on formal research and development in services, is quite scattered on an international basis, which in turn makes international comparisons virtually impossible. Nonetheless, there are some data available for Denmark, which are reported in table 3, as percentages of total business enterprise. Apparently, services made up 28 per cent of total business enterprise R&D in the most recent year, 1991.Further, R&D in services is becoming increasingly important, since the fraction was only about 15 per cent in 1973. By far the largest sector in Denmark

Table 3: The distribution of Danish R&D in services and manufaturing as percentages of total business enterprise R&D, 1973-1991.

No.	Sector	1973	1985	1991
	Total manufacturing	85.23	75.69	72.11
23	Electricity, gas and water	0.24	.	.
24	Construction	0.83	1.17	1.04
25	Transport and storage	.	.	.
26	Communications	1.24	2.86	2.80
27	Commercial and engineering services	2.61	3.09	.
28	Other services	9.84	17.19	24.05
	Total services (23-28)	14.77	24.31	27.89
	Total business enterprise	100.00	100.00	100.00

Source: ANBERD/OECD

is other services, which made up 86 per cent of total R&D in services in 1991.[9] Overall, what these figures imply, is that given R&D in services is becoming more important, more analytical attention should be payed to innovation in these sectors in order to identify the important sources of innovation (the knowledge bases) of these sectors. An important step in this direction is a Danish project under EU's programme for Targeted Socio-Economic Research labelled 'Service in Innovation, Innovation in Services, Services in European Innovation Systems'. The project is going to be carried out in the period from 1996 to 1998.

3.6. Aggregate R&D intensities

The existence of differences in the propensity to conduct R&D accross sectors may cause aggregate R&D expenditure to differ across countries. This is so because the sectoral composition of economies differ among countries, for instance measured as a fraction of value added per sector (as noted in section 3.2). One way of comparing aggregate R&D across countries (given the different sizes of countries) can be carried out by dividing aggregate R&D by aggregate value added (or e.g. production), thus arriving at a number, which can be termed 'R&D intensity', more presisely defined as:

$$RDint._j = \sum_i RD_{ij} / \sum_i VA_{ij}, \qquad (2)$$

where RD_{ij} and VA_{ij} is the R&D and value added conducted in sector i by country j, respectively.

In table 4, the aggregate R&D intensity for nine OECD countries is displayed, plus the average OECD9 intensity.[10] It turns out, that the R&D intensity of Denmark was significantly below the OECD9 average both in 1980 and in 1991.[11] In 1980 Denmark had an R&D intensity of only 45% of the OECD9 avarage, whereas this figure was up to about 56% in 1991, based on an R&D intensity of 4.1%. But even

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[9] Other services is defined as ISIC codes 6, 8 (excl. 8324) and 9, which is: 6 - wholesale and retail trade, hotels and restaurants; 8 - finance, insurance, real estate and business services; 9 - community, social and personal services. 8324 is engineering and technical services, which is included as a separate category (see table 3).

[10] The OECD9 average is based on aggregation allowed for, by applying PPPs.

[11] The first year where value added is included for all sectors in the STAN database.

though there has been a relative improvement in terms of R&D intensity, the absolute figure remains low in an international comparison. Thus, both in 1980 and 1991 only Canada and Italy have a lower R&D intensity.

However, as mentioned above, some of the differences might be accounted for by the sectoral composition of a country, given that countries are specialised differently. It should be mentioned that the question has been analysed in the backgroup report for an OECD evaluation of the Danish Science, Technology and Innovation System (Christiansen & Møller, 1994). However, the report relies on a visual inspection of seven sectors only. One more systematic way of trying to measure this problem is to assume the same structure, in terms of value added as the average OECD9. In doing this (1) can alternatively be decomposed into:

$$RDint._j = \sum_i ((VA_{ij} / \sum_i VA_{ij})(RD_{ij} / VA_{ij})). \tag{3}$$

Thus, if one assume the same structure, in the value added, as the average OECD9, we get:

$$Adj.\ RDint._j = \sum_i ((\sum_j VA_{ij} / \sum_i \sum_j VA_{ij})(RD_{ij} / VA_{ij})). \tag{4}$$

Therefore, the adjusted R&D intensity expresses the R&D intensity of a country assuming the same size of the sectors, in terms of value added, as in the average OECD9. Hence, if a country is specialised in sectors with low levels of R&D intensity, the country will obtain a higher adjusted R&D intensity, when compared to the ‘normal’ R&D intensity. Vice-versa, if a country is specialised in sectors with high levels of R&D activity, the country will get a lower adjusted R&D intensity, compared to the standard R&D intensity.

In table 4 the results of the calculations are displayed. Thus, if Denmark had had the same sectoral composition as the average OECD9, in terms of value added, Denmark would have had an R&D intensity of 4.6, which is about 12 per cent more than Denmark actually spent. If the adjusted method is applied, then Denmark would have an intensity of 63 per cent (1991) of the OECD9 average, against the ‘original’ 56 per cent of the average.

However, the results shown in table 4 are problematic still, since the calculation assumes zero R&D intensity in sectors, where some countries conduct no production.[12] In this context, Denmark has got no production in aerospace and motor vehicles, and will therefore be disadvantaged, if this fact is not taken into

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[12] Which results in a division by zero in formula (4).

Table 4: Total real and total adjusted R&D intensities per country (1980-1991).

	1980			1991		
	R&D intensity	Adj. R&D intensity	Difference (per cent)	R&D intensity	Adj. R&D intensity	Difference (per cent)
Canada	2.3	3.1	38.4	3.3	4.4	35.4
Germany	4.8	5.1	5.9	6.1	6.6	8.3
Denmark	2.4	3.1 (4.6)	29.9	4.1	4.6 (6.7)	11.5
Finland	2.2	3.9	75.6	5.3	6.8	29.7
France	4.2	4.6	8.3	6.3	7.1	12.3
Great Britain	5.9	6.1	2.6	6.2	6.5	3.8
Italy	1.2	2.1	72.7	3.0	4.7	56.6
Japan	4.2	4.3	2.3	7.2	7.4	2.7
USA	7.3	6.9	-4.4	9.5	8.3	-11.9
OECD9	5.3			7.3		

Numbers in brackets are the figures, if DK were assumed to have the same R&D intensity as does the OECD9 average in sectors 20-21 (aerospace and motor vehicles).

Table 5: Total real and total adjusted R&D intensities per country. Excluding aereospace and motor vehicles (1980-1991).

	1980			1991		
	R&D intensity	Adj. R&D intensity	Difference (per cent)	R&D intensity	Adj. R&D intensity	Difference (per cent)
Canada	2.0	3.0	47.3	3.2	4.4	38.8
Germany	4.2	3.9	-6.0	5.1	4.7	-7.3
Denmark	2.4	3.4	41.6	4.1	5.1	22.7
Finland	2.2	4.2	85.1	5.3	7.1	34.1
France	3.2	3.7	17.1	4.7	5.4	14.9
Great Britain	4.7	5.2	11.0	5.3	5.8	9.0
Italy	0.9	1.5	69.5	2.2	3.5	55.4
Japan	4.0	4.0	-0.9	6.6	6.3	-5.5
USA	5.3	5.3	0.5	6.7	6.4	-5.1
OECD9	4.2			5.8		

account.[13]

Two different means of getting around this problem was tried out, since both methods have got advantages and disadvantages. First, one can assume the same R&D intensity, in those sectors with no production, as the OECD9 average. Secondly, one can leave out completely, those sectors (for all countries and for the aggregate).

If the first method is applied, Denmark would have had an R&D intensity of 6.7 (brackets in table 4), which is the equivalent to 92 per cent of the OECD average in 1991, still against the original 4.1 per cent (equivalent to 56 per cent of the OECD9 average). Regardless, this method has got the effect of giving Denmark the advantage of getting an average R&D intensity in a large sector (automobiles) and in a smaller sector, but with very high average R&D intensity (aerospace). Given that Denmark has got no production in these sectors, this might be a strong assumption. Therefore, the second and alternative method was applied, of which the results are reported in table 5.

By totally leaving out the two sectors, in which Denmark has got no production, the R&D intensity in Denmark would be 5.1 per cent, adding up to just about 88 per cent of the average OECD9 of 5.8 per cent (1991). This is to be compared to the ‘original’ unweighted figure, which only added up to 56 per cent of the OECD9 average.

Thus, no matter the method chosen, the specialisation pattern of Denmark is disadvantageous when aggregate international comparisons on R&D intensity is conducted. If the unweighted calculation method is chosen, Denmark rank 7th. out of the nine countries. However, if a method of adjustment is applied, Denmark rank 5th., both in case of the assumption of average intensity in the ‘missing’ Danish sectors, and in the case of completely leaving out the sectors in question, even though the levels are different. One observation worth noting, in this context, is that Denmark rank higher than Germany in both cases of adjustment, whereas Denmark is significantly below Germany in the case of unadjusted, aggregate R&D intensities.

From an international perspective, it can be noted that also Canada, Finland and Italy are severely disadvantaged by their sectoral composition, whereas Great

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[13] Also, given the specialisation pattern of Canada, with no production in instruments, the Canadian figures are problematic. But since this sector is on average small, the problem is not as serious as in the Danish case. The USA has got no significant production in shipbuilding, this not being a serious problem, given that this sector is, on average, both small and has got a low R&D intensity.

Britain, Germany, Japan and the US are particularly advantaged by the sectoral composition of value added.[14]

Looking into the dynamics of R&D intensities, an observation which can be made, is that Denmark has been converging towards the OECD9 mean, both in terms of ‘actual’ R&D intensity and in terms of the adjusted intensity, in the period from 1980 to 1991. In terms of unadjusted intensity (table 4), Denmark had an R&D intensity of about 45 per cent of the OECD9, in 1980, this figure was up to about 56 per cent in 1991. In terms of adjusted R&D intensity, the movement was from about 81 per cent of the intensity of the OECD9 in 1980, to 88 per cent in the most recent year, 1991 (table 5).[15]

Another interesting observation, in the case of Denmark, is that the difference between the adjusted intensity and the unadjusted figure, is becoming smaller in the period from 1980 to 1991, thus implying that Denmark is becoming increasingly specialised in sectors with a higher R&D intensity, even though it should be noted (as pointed out above) that Denmark is generally specialised in sectors with a lower R&D intensity still, as compared to the OECD9.

3.7. R&D intensities at the sectoral level

So far, we have looked at aggregate R&D intensities only. However, it might be interesting to look at R&D intensities at the sectoral level, in order to reveal what lies behind the aggregate figures. Figure 2-5 exposes the R&D intensity versus the size of the sectors in terms of per cent of total value added. Figure 2 and 3 are sectoral comparisons, in of terms Denmark versus the average OECD9 divided in to ‘high’ and ‘low’ tech respectively, whereas figures 3-4 are Danish comparisons, between 1980 and 1991. Also figures 3-4 are divided into ‘high’ and ‘low’ tech., respectively. It can be seen from figure 2 (‘high’ tech) that Denmark is specialised in producing pharmaceuticals, since the percentage of value added of total is higher than in the OECD9 and that the associated R&D intensity is more than 30 per cent higher than the intensity of the OECD9. However, in the two core

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[14] It should be noted that the size of the US economy influences the aggregate the figure on OECD9. Therefore, only the US is *absolutely* disadvantaged, when adjusting for industrial composition, in table 5. However, also Germany, Great Britain and Japan are *relatively* disadvantaged.

[15] Using the method of leaving out aerospace and motor vehicles in all calculations.

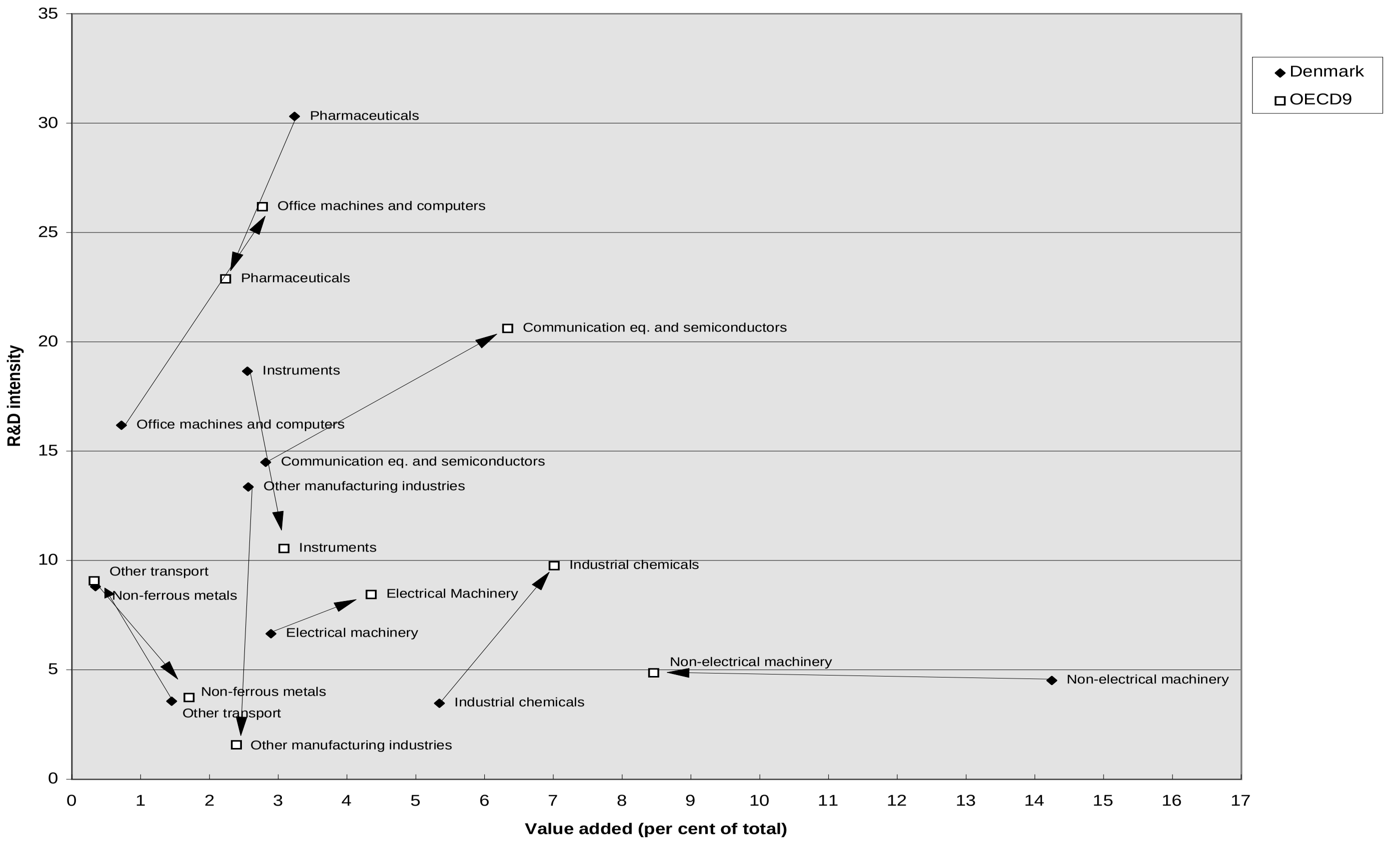

Figure 2:: R&D intensity versus size distribution of ISIC sectors (‘high tech.’), Denmark compared to OECD9 (1991).

Source: Calculations based on STAN and ANBERD (both OECD).

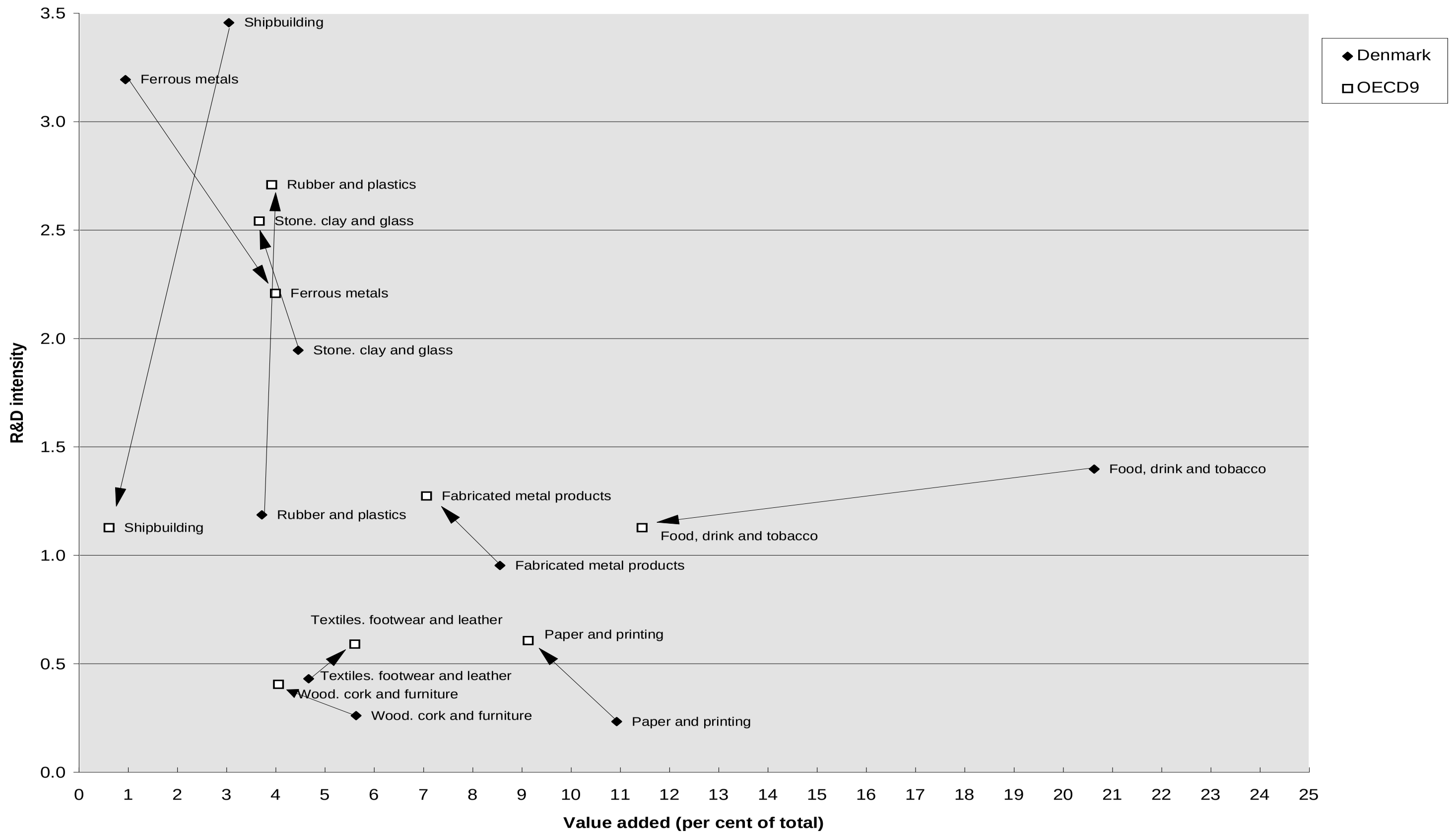

Figure 3: R&D intensity versus size distribution of ISIC sectors ('low tech.'), Denmark compared to OECD9 (1991).

Source: Calculations based on STAN and ANBERD (both OECD) information technology sectors, office machines and computers and communication equipment and semiconductors Denmark is under specialised (in terms of value added) and has got a significantly lower R&D intensity, as compared to the OECD9. In addition (and as mentioned before) Denmark has got neither production or value added in the two ‘high’ tech. sectors, aerospace and motor vehicles. All in all, Denmark has got a higher R&D intensity in four out of the ten ‘high tech.’ sectors, when compared to the OECD9, whereas the intensity in the OECD9 is higher in five cases. In a sector, which seems particularly important in Denmark, namely non-electrical machinery, the Danish R&D intensity is nearly equal to the average.

In the ‘low tech sectors’, displayed in figure 3, it can be seen that shipbuilding is comparatively much more R&D intensive in Denmark, and is economically more important than in the OECD9[16], even though the sector remains relatively small. The economically most important sector[17] in the Danish case was, in 1991, food, drink and tobacco; a sector which is nearly twice as large, as it is in the OECD9 average. This sector is also more R&D intensive (24%), when compared to the average. Sectors, in which Denmark is significantly below the OECD9 average in terms of R&D intensities, include rubber and plastics; and stone, clay and glass, whereas the differences in the rest of the ‘low tech.’ sectors are smaller.[18]

3.8. The dynamics of R&D expenditure in Denmark and OECD9

One way of looking at the dynamics of R&D expenditure can be by way of applying a 'Constant Research and Development Share’ methodology, often used in an empirical trade context (cf. Fagerberg and Sollie, 1987). The starting point is whether or not a country get to do more R&D as a percentage of total OECD9 R&D over time, between two periods. As an example, Canada’s share of OECD9 R&D made 1.27 per cent in 1980, rising to 1.35 per cent in 1991, this being equivalent to a growth of 6.7 per cent. The basic idea of the method is then to

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[16] Shipbuilding makes up nearly three times as much in Denmark (of total value added) as in the OECD9 (3.04% and 1.13% respectively).

[17] When measured directly, without taking knowledge spillovers into account.

[18] See Appendix table A1 for an international comparison of R&D intensities at the sectoral level.

decompose the aggregate figure, in such a way that structural change gets isolated. It is then possible to say something about whether a rise (or fall) of a country's share of OECD9 R&D is due to (i) the 'right' ('or wrong') specialisation pattern; (ii) a movement into sectors with fast-growing (or stagnating) R&D expenditure; (iii) a movement out of sectors with generally stagnating R&D expenditure (or fast-growing), and finally whether the rise (or fall) is due to the fact that the country might be gaining shares of R&D, assuming that the structure is the same between the two periods in question.

Below is a presentation of the methodology to be applied. Δ denotes a change from year 0 to year 1. Superscript 0 denotes the starting year (year 0).

$a_j = \sum_i RD_{ij} / \sum_i \sum_j RD_{ij}$ (a country's aggregate share of total OECD9 R&D)

$a_{ij} = RD_{ij} / \sum_j RD_{ij}$ (a country's share of a given sector in terms of R&D)

$b_{ij} = \sum_j RD_{ij} / \sum_i \sum_j RD_{ij}$, (a sector's share of total OECD9 R&D)

where RD_{ij} denotes formal research and development conducted by country *j* in sector *i*. The rate change of a given country's aggregate share of total OECD9 R&D (Δa_j) can be decomposed into:

$$\Delta a_j = \sum_i (\Delta a_{ij} b_{ij}^0) + \sum_i (a_{ij}^0 \Delta b_{ij}) + \sum_i (\Delta a_{ij} \Delta b_{ij}) \qquad (5)$$

R&D Share effect   Structural effect   Adaptation Effect

Thus, the R&D share effect measures whether a country is gaining or loosing shares of OECD9 R&D, assuming a fixed structure between the two periods. The structural effect measures whether a country is gaining or loosing R&D shares because of a 'right' or a 'wrong' specialisation pattern. Finally, the adaptation effect measures whether a country is gaining or loosing shares because of an active movement into (or out of) the 'right' sectors or a movement out of (or into) the 'wrong' sectors. However, since for instance, a positive value of the latter effect can be caused by either a movement into to 'right', or a movement out of the 'wrong' sectors, it can be useful to further decompose the 'adaptation effect' and distinguish between a 'growth adaptation effect' (positive, if a country move into the fast-growing sectors) and a 'stagnation adaptation effect' (positive, if a country move out of the stagnating sectors):

$$\sum_i (\Delta a_{ij} \Delta b_{ij}) = \sum_i \Delta a_{ij} \frac{\Delta b_{ij} + |\Delta b_{ij}|}{2} + \sum_i \Delta a_{ij} \frac{\Delta b_{ij} - |\Delta b_{ij}|}{2} \qquad (6)$$

Adaptation Effect   Growth Adaptation Effect   Stagnation Adaptation Effect

Thus, in other words, if (6) is inserted into (5) we get that the four components, namely ‘R&D share effect’, ‘the structural effect’, ‘the growth adaptation effect’, and the ‘stagnation adaptation effect’ add up to the total rate of change (Δa_j) of a given country’s share of OECD9 R&D expenditure.

Since the relative growth of a sector in terms of R&D expenditure, probably reflects, whether growth in technological opportunity (Malerba and Orsenigo, 1990, Nelson and Winter, 1982) is relatively high or low in that sector, a possible interpretation of the three latter effects is that these effects measure a given national innovation system’s ability to move into sectors with relatively high levels of technological opportunity.[19] Thus, if the structural effect for a country is positive and high, this means - following the interpretation suggested above - that the national innovation system has been ‘fortunately’ specialised in the initial year; being specialised in sectors which has generally experienced high growth in technological opportunity (indicated by high levels of R&D growth). Following the same logic, if the two latter effects are high and positive, it indicates that a NIS has *actively* moved into sectors with higher levels of technological opportunity (the growth adaptation effect), or actively moved out of a sector with lower technological opportunity (the stagnation adaptation effect).

Table 6, displays the results from the standard calculations described above.[20] It can be seen that Denmark’s share of total research and development - together with Finland, Italy and Japan - has risen substantially (23 per cent), in the period in question, but from a very low level (0.23 per cent of total OECD9 R&D in 1980). If then technological opportunity had grown at equal rates, across sectors (measured by the R&D share effect), Denmark’s share of total OECD9 R&D would have risen about 31 per cent. Accordingly, the combined effect of the structural effect and the stagnation adaptation effect means that Denmark’s share of total became about 9 per cent points lower, compared to what it would have been, if technological opportunity had grown at equal rates across sectors. Of those 9 per cent, about 3½ per cent points is due to the fact that Denmark was specialised in slow growing sectors in the initial year, in terms of R&D expenditure and thus low levels of technological opportunity. About 5½ per cent points (of the 9) is due to the fact that Denmark has increasingly moved into

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[19] Technological opportunity conditions reflect a firm’s likelihood to innovate, given the amount of investment in R&D.

[20] The methodology applied is, generally speaking, sensible to choices of both the initial and the final year. However - at least what concerns the Danish case - this was not seen to be a specific problem, in this case, since alternative calculations, in which the two periods were split into two (1980-85 and 1985-91), are consistent with the results reported above.

Table 6: Constant R&D share effects of the OECD9 countries

	Share of total R&D						
	1980	1991	Difference (80-91)(%)	R&D Share Effect	Structural Effect	Gr Adap. Effect	Str. Adap. Effect
Canada	1.27	1.35	6.74	6.91	-5.09	2.63	2.29
Germany	11.90	10.98	-7.72	-4.72	-2.92	-0.43	0.35
Denmark	0.23	0.29	23.37	31.11	-3.59	1.31	-5.46
Finland	0.27	0.42	55.34	72.10	-8.16	1.74	-10.33
France	6.60	6.71	1.61	1.70	1.78	-0.94	-0.93
Gr. Britain	8.00	5.97	-25.40	-28.16	3.40	-1.30	0.66
Italy	2.38	3.15	32.31	33.52	4.81	0.66	-6.67
Japan	14.85	23.04	55.23	64.30	-4.13	4.04	-8.98
USA	54.50	48.08	-11.77	-14.68	1.01	-0.81	2.70
OECD9	100.00	99.99					

Source: STAN/OECD

sectors with lower levels of technological opportunity, in the period from 1980 to 1991. Nevertheless, the growth adaptation effect is making a positive, but relatively small (1.3 per cent points), contribution to the rise in Danish share of OECD R&D, indicating that the Danish innovation system is to some extent increasing its share of the fastest-growing sectors in terms of OECD R&D expenditure.

In addition, to the aggregate effects presented above, it is possible to decompose all the four effects into sectoral components. In other words, for instance the structural effect, is made up of the contribution from the 22 ISIC sectors. Thus, one can say something about, which sectors makes the largest contribution to the negative Danish structural effect of 3.6. From table 7, it can be seen that the largest contribution to the negative effect stems from non-electrical machinery (- 1.7 percentage points) and other manufacturing industries (- 4.42 percentage points), where a combination of high Danish specialisation in these two (slow-growing) is a large part of the explanation for the negative structural effect. If this closer inspection of the aggregate affects is conducted in the Danish case, one striking feature is that pharmaceuticals makes up 14 percentage points of the total growth of the Danish share of OECD9 R&D expenditure of about 23 per cent. In the case of Danish pharmaceuticals, Denmark has been both specialised in this fast-growing sector (as indicated by the positive structural effect), and has

Table 7: Constant R&D effects for Denmark - decomposed into sectoral impact in the aggregate 1980-1991.[21]

No.	Sector	All effects combined	R&D Share Effect	Structural Effect	Gr Adap. Effect	Str. Adap. Effect
1	Food, drink and tobacco	1.09	1.55	-0.39	0	-0.08
2	Textiles, footw. and leather	-0.28	-0.22	-0.08	0	0.02
3	Wood, cork and furniture	-0.24	-0.04	-0.21	0	0.01
4	Paper and printing	0.00	0.19	-0.15	0	-0.04
5	Industrial chemicals	-2.59	-2.53	-0.09	0	0.03
6	Pharmaceuticals	14.25	7.59	4.43	2.23	0
7	Petroleum refineries	0	0	0	0	0
8	Rubber and plastics	-0.65	-0.25	-0.46	0	0.06
9	Stone, clay and glass	-1.06	-1.03	-0.03	0	0.01
10	Ferrous metals	0.67	1.08	-0.07	0	-0.34
11	Non-ferrous metals	0.70	0.78	-0.02	0	-0.06
12	Fabricated metal products	0.54	1.01	-0.31	0	-0.16
13	Non-electrical machinery	6.00	8.90	-1.74	0	-1.17
14	Office mach. and computers	-1.41	-2.46	2.13	-1.07	0
15	Electrical machinery	2.20	4.97	-1.15	0	-1.61
16	Comm. eq. and semiconduc.	1.69	0.83	0.79	0.06	0
17	Shipbuilding	-0.38	0.64	-0.86	0	-0.16
18	Other transport	0.97	0.80	0.07	0.09	0
19	Motor vehicles	0	0	0	0	0
20	Aerospace	0	0	0	0	0
21	Instruments	3.76	5.31	-1.03	0	-0.52
22	Other manufact. industries	-1.89	3.99	-4.42	0	-1.46
	Total	23.37	31.11	-3.59	1.31	-5.46

Source: STAN/OECD

increasingly moved into this sector (as indicated by the positive growth adaptation effect). Also non-electrical machinery and instruments make a relatively large positive contribution to the total Danish gain of R&D share. However, the gain stem from increasing shares in stagnating sectors (lower levels of technological opportunity) as indicated by the large and positive R&D share effects, combined with the negative structural- and stagnation adaptation effects.

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[21] Similar calculations for Canada, Germany, Finland, France, Great Britain, Italy, Japan and the US are available from the author on request.

3.9. Some conclusions concerning the Danish production system and technological specialisation

The first part of this section has described the Danish business sector in terms of sectoral distribution. In this context some areas of specialisation were identified. An interesting aspect of the Danish system is that an area which is not so well researched, namely services, accounted for more than 25% of total Danish R&D. What was not so surprising is Denmark's specialisation in food, drink and tobacco, pharmaceuticals, non-electrical machinery and instruments, and under specialisation in automobiles, aerospace and information technology, generally. Such relative strengths and weaknesses remain significant, whether measured as value added, production, employment or R&D.

In section 3.6 an attempt was made to asses whether the low R&D intensity in Danish manufacturing industry is caused by a disadvantageous sectoral specialisation. It was shown that this is to some extent the case. However, if firms in a NIS are not able to conduct meaningful technological search in technologically unrelated areas, because the path dependent nature of technological change[22], enhanced durable user-producer interaction and so on, it is not meaningful to conclude that Denmark should dramatically change sectoral specialisation because the sectors in which the country is specialised, appear to offer generally low levels of technological opportunity. Thus, given such rigidities, Denmark will not, in the foreseeable future, get a (real) R&D intensity at the *level* of the OECD9. However, this not to say that the Danish system is performing well in terms of R&D performance. It remains a fact that Denmark's R&D intensity is significantly below the OECD9 average. What is worrying then, is that not more resources are allocated to R&D in 'medium' or 'low tech.' sectors in Denmark, since more resources should be available for conducting research in these sectors, given that Danish firms in 'high tech.' sectors are using considerably less resources compared to what is used by the same sectors in other countries, since the relative size of these sectors are smaller in Denmark (except from pharmaceuticals). Thus given that Danish firms are (heavily) specialised in producing non-electrical machinery and food, drink & tobacco it is particularly worrying that these sectors are not conducting significantly more R&D pr. value added than does the OECD9. Moreover, it is worrying that Danish firms are generally conducting less R&D in 'low tech.' (> 3.5 R&D intensity) in comparison with OECD9, since Danish firms, in only three out of ten 'low tech.' sectors are

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[22] An example of the path dependent nature of technological development is pharmaceuticals in Denmark, where the competencies have been built up over more than seven decades.

conducting significantly more R&D than does the OECD9 average.

From a dynamic perspective, it is a positive fact that Danish firms are conducting a larger share of OECD9 R&D in the period 1980 to 1991. However, it should be noted that the gain is not ‘earned’ by the whole business part of the NIS; the gain is largely due to an increase in R&D expenditure in only three sectors, out of 22 (pharmaceuticals, non-electrical machinery and instruments).

4 Transfer of knowledge in the Danish innovation system

4.1. Introduction

Whereas the previous chapter focused on the size and performance of individual sectors, this chapter is going to describe data sources and analytical possibilities for measuring *knowledge flows* in the Danish NIS, as outlined by the OECD. The chapter will analyse and describe the knowledge flows presented in chapter 2; namely:

a. flows embodied in commodities, traded between sectors
b. flows going through other inter-firm (mainly user-producer) relationships
c. flows facilitated via university-industry relations
d. flows facilitated via the interaction between other (other than university) public institutions and business firms
e. flows embodied in people (personal mobility)

Firstly however, the large innovation surveys, CIS and PACE will be described generally, and specifically in relation to Denmark. Secondly, a section will briefly describe some analytical possibilities of measuring the flow of knowledge embodied in commodities (point a). Thirdly, examples will be given in terms of using CIS data for analysing user-producer interaction (point b). In addition, illustrations of how CIS data (and to a smaller extent PACE data), can be applied as indicators of research co-operation within the enterprise sector (also point b). Fourthly, the impact of the Danish technological infrastructure will be discussed. The focus of this fourth section will be divided into two subsections; one section on Danish science parks and one on the technological service system in Denmark (points c & d). Fifthly, a section will present analytical possibilities for measuring labour market flows (point e). Finally, the chapter will describe some of the important linkages (interaction) in four different types of sectors, in which Denmark is strongly specialised, as a means of illustrating the differentiated nature of technological accumulation across sectors.

4.2. The databases suitable for quantitative measurement of knowledge flows

4.2.1. The Community Innovation Survey (CIS)

General information on CIS

The background for the CIS project is a set of mostly independent surveys on innovation carried out in the 1980s. The experience from these surveys resulted in an OECD manual in 1992 (‘OECD Proposed Guidelines for collecting and interpreting data on technological innovation’ - the Oslo manual) which is intended to be a basis for more coherent future surveys. Eurostat and DG-XIII developed CIS in collaboration with independent experts and the OECD, resulting in the final, harmonized questionnaire in June 1992. The objective of CIS is

> to collect firm-level data on inputs to, and outputs of, the innovation process across a wide range of industries and across Member States and regions, and to use this data in high-quality analysis, which among others, will contribute to the future development of policies for innovation and the diffusion of new technologies at Community, Member States and regional level (Archibugi *et al.*, 1994, p. 1).

CIS, or a closely similar approach, is also implemented - or is planned to be implemented - in some non-member states. This goes for Canada, USA, Norway, Finland, Austria, Australia, South Africa. By the end of September 1995, Eurostat will have finished data processing.[23] The database will then contain a large variety of variables on innovation in approximately 40.000 firms.

Variables in CIS

The information collected in CIS is perhaps a bit biased towards product innovation, but some parts of the questionnaire include process innovation as well.

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[23] Estimating item-non-response, applying raising factors, checking for not logical answers etc.

In addition, it asks a set of questions on co-operation, use and exchange of information and barriers to innovation. In appendix table 2 is a list of the groups of variables in the questionnaire.

The questionnaire is aimed at enterprises within manufacturing and was generally sent to a stratified sample of enterprises with relatively low cut-off points. CIS was implemented for the first time in the autumn 1993. As such CIS may be seen as a pilot project and the experiences from the first implementation is valuable in relation to a future survey. Use of the data for purposes of comparing across countries is still restricted to some of the countries due to differences in sample, questions and implementation methods in the member states.[24] Some of the questions asked are quite new to the firms and consequently answers on those questions are generally less precise. This goes in particular for the questions on innovation costs and the distribution of sales on product life cycle stages. These questions are also among those with the lowest response rates.[25]

Even if there remains much to be done in terms of improving implementation of the surveys, CIS provides the best data source for mapping of the nature of the innovation process in manufacturing compared to other data available.

Implementation of CIS in Denmark

The survey in Denmark was implemented by Statistics Denmark and co-financed by the Ministry of Industry. The questionnaire was sent to 1313 firms of which 674 responded. The sample was selected by stratified random sampling. All firms in the frame with more than 199 employees are in the sample. The individual respondent were either general manager, chief accountant or technology/R&D manager. Twice, reminders were sent and the total response rate was 51%. This rate differed according to size of firms. Thus, approximately 63% of firms with 200 and more employees responded but only 48% responded in small firms. Non-response analysis was performed, which showed that the characteristics of the non-responding firms approximately corresponded to those of the responding firms. This non-response analysis had a response rate of 84%

Raising factors have been calculated taking into account both the distribution of answers on size groups and industries and the non-response analysis.

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[24] See the evaluation reports by Archibugi *et.al.* (1994) for an in-depth assessment of the data quality as well as the implementation in each member state.

[25] One country evaluation lists the time used by respondent to fill in the questionnaire to be on the average 120 minutes ranging from 60 to 210 minutes.

Table 8: Number of manufacturing firms in the frame sample, responding, distributed on size groups.

Employees	Frame	Sample	Responding
20 to 49	1786	385	176
50 to 99	626	320	154
100 to 199	368	298	149
200 and up	291	311	195
Total	3071	1314	674

Use of Danish CIS data

The Danish CIS data has been analysed in a project financed by the Mimistry of Industry. The analysis is presented in two books by Jesper Lindgaard Christensen and Arne Kristensen in a series of books by the Ministry of Industry (Christensen and Kristensen, 1994, Christensen and Kristensen, 1995). A third book will be published in the beginning of 1996.

Possibilities of analysis are many, as will also be obvious from the huge range of variables presented in appendix table A2. In the Danish case possibilities are even bigger since we have supplemented the CIS data with accounting and investment data, at the firm level. This gives a unique opportunity to explore issues related to the relationship between economic performance of the firm and innovation activity.

Examples of analysis with Danish CIS data are given in sections 4.4 - 4-5 below in relation to those of the indicators listed in chapter 2 of this paper, which may be analysed with CIS data.

4.2.2. PACE data

The PACE survey (PACE = Policies, Appropriation and Competitiveness in Europe) was financed by the EU SPRINT programme. The coordination was undertaken at MERIT, University of Limburg, The Netherlands, and the Danish part of the survey was undertaken by IKE - Department of Business Studies, Aalborg University in co-operation with the Ministry of Research.

The PACE survey is a follow-up of the YALE survey which was undertaken at Colombia University USA in the beginning of the 1980s. The objective is to analyse a selected part of manufacturing firms, i.e. the largest and most R&D-intensive. 1500 of these firms in Europe was meant to be included in the sample of the survey.

Implementation of PACE in Denmark

In Denmark the frame should - according to the above criteria - include only 25 firms. However, in order to get more observations the frame was extended to 58 firms.[26] One of these was excluded and of the remaining 57 firms 50 responded (88%) on the rather detailed and large questionnaire. Non-responding firms were not systematically biased in any way. Approximately 1/4 of the production value and approximately 3/4 of the internally financed R&D in the manufacturing sector in Denmark is covered by these 50 firms.

Variables in PACE survey

The PACE questionnaire is more wide-ranging and specific than the CIS survey. It concentrates on ordinal rankings of types of knowledge flow or support within technological knowledge, research output and methods of access to these results, appropriability, and public policy. Appendix table 3 shows examples of variables in the survey.

Although the data is of course biased towards the R&D-intensive part of manufacturing, they do offer opportunities to go a bit further than CIS data with respect to the indicators discussed in the OECD framework and in chapter two of this report. In particular, horizontal and vertical linkages could be further analysed as could the type and economic importance of bridging institutions. As such the PACE data may be regarded a valuable supplement to the CIS survey.

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[26] In other small EU-countries a similar strategy was followed.

4.3. Embodied knowledge flows

This section will briefly describe some analytical *possibilities* of measuring the flow of knowledge embodied in commodities, an area which will be further researched in the context of the DISKO project. In this regard, a combination of Danish input-output data and, for instance, R&D data can be applied. Input-output data basically measure the transfer of raw materials/semi manufacture between sectors in the economy. Hence, input-output tables can be viewed a means of disaggregating the national income into value added per sector (by deducting input from output). In the Danish case there are basically 117 individual sectors in the input-output statistics, which can be further aggregated, such as to match the ANBERD data. There are a number of technical complications concerning the use of input-output tables in the measurement of economic structure, and structural change, but these matters will not be discussed here (see e.g. Jensen, 1996).

An important problem in the context of using input-output data as a sole indicator of innovative linkages is that large economic transfers might in reality reflect ‘mature’ linkages, where the transaction consists of routine deliveries and contain few possibilities of change and development (Andersen, 1992). Nevertheless, since input-out matrices measure inter-sectoral transfers of goods, it is possible to multiply the R&D intensity of the delivering sector by the transfer to the receiving sectors, thus arriving at a number which reflect ‘indirect R&D’ in the receiving sector, originally conducted in the delivering sector. Subsequently, all the indirect R&D from all delivering sectors can be summed up, and one arrive at a number measuring the total indirect R&D of a given (receiving) sector. This can be done for all ANBERD sectors. Such a methodology is illustrated in figure 4, where focus is chosen to be on a single sector (sector A), and its relation to the three other sectors in the given NIS. Using the methodology, mentioned above, the input of indirect R&D from the other sectors (B, C & D) can be aggregated into a single number[27], which can be illustrated by means of figure 4, where the total indirect R&D is equal to the sum of I_A, I_B, I_C & $I_{D.}$ In addition one can see how important e.g. sectors A’s output is for the other sectors. In this way all indirect R&D in- and output flows can be mapped between all sectors (in a matrix), and then *indicate*, where strong innovative linkages are present, constituting what might be termed nodal points in the NIS. In this context it is possible to make an inspection of the *change* of the indirect R&D linkages from 1980-1991, which in turn can help further to sort out what are the dynamic nodal points.

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[27] The size of the indirect R&D flows can - as in figure 4 - be displayed as the width of the arrows.

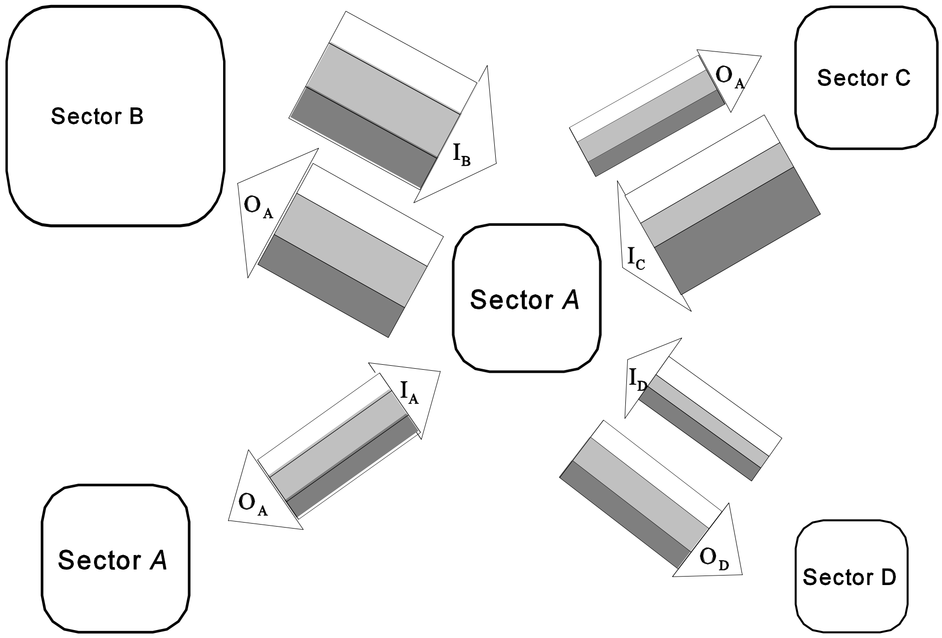

Figure 4: An example of using input-out data and R&D data as measurement of indirect R&D flows out of, and into a sector in the economy.

Also an international comparison might reveal interesting aspects of linkages in national innovation systems, even though some caution is called for, given that countries have got differentiated production systems. Hence, two national systems might be equally efficient, even though the degree of division of labour (degree of vertical disintegration) differ, which in turn might reflect a specific specialisation in terms of Pavitt sectors (specialised suppliers have got more external linkages, while science-based firms have got less).

However, given that when standard R&D data is collected, a narrow definition of R&D is applied, it might be useful to employ CIS data instead/or in addition, as a measure of R&D, since the definition of R&D in this data, does not exclude innovation conducted in direct connection with production. Thus the R&D intensities can be calculated on the basis of CIS data instead. The disadvantage of such an approach is that CIS data has been collected for 1993 only, which of course makes analysis of change impossible.

A final - but technically more difficult - idea is to use the level of education in the delivering sector to calculate the ‘knowledge intensity’ of that sector. One indicator could be the number of engineers employed in delivering sectors, and on the basis of this and input-output data, calculate the ‘indirect engineer’ transfer to the receiving sector. Detailed data on the education composition of the workforce is available in the Danish *IDA* (for more detailed description on this database, see below) database, which contains information on the level of the individual person. Thus, it is possible to make this data compatible with Danish input-output data. An even more advanced method would be to use different kind of labour employed, by the delivering sectors, and then attribute an (arbitrary) weight to the types of labour (e.g. engineers, technicians, skilled labour). Thus, it would be possible to add to the map (figure 4) the relative importance of transfer of different types of labour (embodied in products) between sectors, as indicated by the width of the gray scale in the arrows in figure 4. The latter type of analysis has the advantage of reducing the level of uncertainty in comparison to other types of data, because the labour market IDA data is not based on attitudinal data (questionnaires). But there are also some disadvantages of using such data, since what might be a persons initial education, can be radically changed due to on-the-job training in the labour market.

4.4. CIS data for Denmark in relation to user-producer interaction

Some of the questions in the CIS questionnaire does address user-producer interaction. This goes e.g. for the sources of information for innovation activity where the role of customers, suppliers etc. are assessed. Also the exchange of technology in terms of firms purchasing or selling various forms of technology may be taken as an indirect yardstick on the qualitative aspect of user-producer interaction.

Table 9 shows results from the Danish data with respect to those of the variables relevant for user-producer interaction based on the question about the importance of different information sources for innovation activity. For the purpose of showing different possibilities of breaking down results they are in table 9 distributed on Pavitt-sectors and size groups respectively.

Table 9: Selected external sources for innovation distributed on Pavitt-sectors. Share of firms who assess a source as important.

Market factors	Clients or costumers	Suppliers of materials and components	Suppliers of equipment	Competitors	fairs, exhibitions
Total	67	44	42	36	32
Science-based	66	46	37	30	36
Supplier dominated	60	41	45	33	31
Scale intensive	59	42	46	31	18
Specialised suppliers	88	46	33	46	46

Technology factors	Conferences, meetings, journals	Technical institutes	Universities and higher education inst.	Government laboratories
Total	20	16	10	9
Science-based	29	20	29	24
Supplier dominated	16	15	5	5
Scale intensive	27	16	10	12
Specialised suppliers	17	13	11	7

These results are in themselves very interesting in a policy context, because they show us something about, what *initiates* innovation (the source of innovation). It is clearly seen that market factors play a very important role in this context (and significantly more than the ‘technology factors’). However, it should be stressed that the table above says nothing about what is the important factor in *carrying out* the innovation. In addition, it is possible to make various cross tabulations and regressions in order to investigate what correlations might be, between these results and results from other parts of the questionnaire. The other group of indicators of user-producer interaction, mentioned above, (exchange of technology) is not accurate in terms of quantification of the acquisition and transfer of different types of technology. Rather than asking for the amount of money spent on/earned on purchase and sale of technology the questionnaire only counts the number of firms engaged in various types of sale and purchase. Some of the categories in these questions may, however, give us an indication of the content of user-producer interaction, even though users and producers are not the direct focal point in the questions. Most of the types of transfer should rather be termed producer-producer interaction.The data could have been broken down on country of origon of purchase and sales of technology but is here shown in the

Table 10: Purchase of technology distributed on types of technology and size of firms. Share of firms who bought technology.

	Purchase of equipment	Communi-tion with other firms	Consultant service	Hiring skilled employees	Licenses, etc.	R&D contracted out	Purchase of other enterprises
Total	64	36	32	29	21	12	10
Less than 50 employees	63	27	27	26	14	6	12
50-99 employees	60	38	26	32	20	8	7
100 - 199 employees	61	37	34	24	17	10	4
200 - 399 employees	71	37	31	30	25	8	10
More than 399 empl.	68	40	43	32	33	32	22

Table 11: Sales of technology distributed on types of technology and size of firms. Share of firms who sold technology.

	Communi-cation	Licenses etc.	Mobility of skilled employees	Consu-ltant service	Sales of equipment	R&D performed for others	Sale of part of the firm
Total	25	15	15	14	12	5	3
Less than 50 employees	23	5	10	17	12	1	1
50-99 employees	24	12	14	16	12	5	2
100 - 199 employees	23	11	14	13	10	5	2
200 - 399 employees	20	14	17	6	12	4	2
More than 399 empl.	33	36	19	18	14	10	10

dimensions, type of technology, and size of firm. It is clearly displayed in the tables 10 & 11 that purchases of technology is on a higher level than sales of technology. This pattern could be expected because firms buy technlogy from the non-manufacturing sector and because the same firm may sell technology to several other firms, which will only count as one selling firm but as many buying firms. Purchase of equipment is clearly the type of technology most firms buy whereas exchange of information is the type of technology sold by most firms. Both sales and purchases of technology is more frequent in large firms compared to other size groups. In particular sales of part of the firm/purchase of other

Table 12: Flows of product innovations between sectors. Share of (percent) firms (rows) who respond that they transferred new means of production, raw material, or semi manufacture to users in the other sectors (columns).

OUTPUT/INPUT	Science-b.	Sup. dom.	Scale i.	Spec. sup.
Science-based	39	18	19	71
Sup. dominated	7	48	34	14
Scale intensive	8	21	58	11
Specialised suppliers	5	41	42	31

Table 13: Flows of information between sectors. Share of firms (percent) within sectors (rows) who respond that users in other sectors (columns) participated in the development of new means of production, raw material or semi manufacture

PRODUCER/USER	Science-b.	Sup. dom.	Scale i.	Spec. sup.
Science-based	31	5	5	27
Sup. dominated	2	28	15	6
Scale intensive	3	13	30	8
Specialised suppliers	3	11	29	15

entreprises and R&D show marked differences between firms with more than 400 employees and other firms.

The most adequate indicator in CIS on user-producer interaction is unique to the Danish survey. Some of the countries added one or two questions to their surveys, and this goes for the Danish survey as well. One of the specific questions asked in the Danish questionnaire, focused on the industry of the user of product innovations and on whether the users participated in the development process. With answers from this question it is possible to make a kind of ‘innovation input-output’ tables illustrating what industries co-operate in the innovation process.

Above is illustrated such tables, here broken down according to the Pavitt taxonomy. Table 12 shows the flow of product innovations between sectors, whereas table 13 shows information flows in terms of users participating in the development of the new product. One interesting feature of tables 12 and 13 is that they demonstrate the role of science-based firms in distributing knowledge and new artefacts, through the firm’s vertical linkages, whereas firms in this sector is not so dependent on input from other sectors. Another observation is that the Danish data confirm the observation by Pavitt (1984) that scale intensive and specialised suppliers live in a ‘symbiosis’, since they are heavily dependent on each other in the innovation process. However, it has to be pointed out, that the data says nothing about the relative importance of the external knowledge sources. What the data report, is whether users were involved in the process or not.

Further analysis could be undertaken on the response to this question, including different aggregations and investigations of the relationship between these results and other parts of the questionnaire. In a research project starting in 1996[28] this question will be used for exploring further aspects of the Danish national innovation system.

4.5. CIS and PACE data as indicators of research co-operation

A section of the CIS-questionnaire is devoted to R&D co-operation and this co-operation is distributed across both regions and type of partner. The OECD (1995) has asked whether there are indicators on:

- firms reporting research co-operation by partner and;
- relative importance of the main institutional forms of co-operative research.

The CIS data cover the first point fully and also the second point with the modification that these data include development and not only research.[29] However, the latter may be analysed with CIS data if the relative importance is viewed on an aggregate level and not within the single enterprise. This seems as the most relevant measure, so in conclusion the first two points may be analysed with CIS data. The partners for R&D co-operation in CIS are the following:

- clients/customers;
- suppliers;
- mother-/daughter-/sister enterprises;
- competitors;

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[28] The DISKO-project, supported by the Ministry for Industry.

[29] Christensen and Kristensen (1996) analyses research co-operation by partners in five different European countries, using CIS data.

Table 14: R&D-co-operation of R&D-performing firms by partners and size of firms

Firm size	Domestic, private partners	Domestic, public partners
20 to 49	32	25
50 to 99	45	33
100 to 199	53	41
200 to 499	43	36
500 and above	63	71

- joint ventures;
- consultants;
- government laboratories;
- research institutes;
- universities / higher education;
- industry-operated R&D labs.;
- other;

In table 14 is given an example on R&D co-operation in Danish firms by groups of partners, which also show that point two may be described with these data. The table shows that in the Danish case there is quite a clear-cut relationship between the size of firms and the propensity to have R&D co-operation. The table also shows that many firms are involved in research co-operation, but whether this is true also in an international comparison, is beyond the scope of this report. In addition, the example and the description of the questionnaire above, show that the data may be used as a proxy for some part of the indicator asked for by the OECD (1995), namely the number and economic importance of formal co-operative projects. With respect to the latter it is not possible to specify the number and economic importance of the total number of undertaken co-operative projects, but the number of firms participating in such co-operative projects may be specified.

Two of the issues emphasised by the OECD, namely, user/producer relationships and research co-operation,can be analysed with these data. However, a full description could benefit from supplementary data. In particular the PACE data may be a useful source of additional information.

In table 15, is an example on data from the Danish PACE survey, which illustrate some of the possibilities in relation to the indicators just mentioned. An important

Table 15: The importance of different kinds of contact to the public research system. Percent of firms who assess a type of contact as important/ who actually use this type of contact.

N=50	Assessment	Actual contact (Denmark only)
Publications and technical reports	38	86
Public conferences and meetings	38	74
Hiring skilled labour	42	80
Informal contact to public researchers	50	88
Exchange of labour with public research institution	20	42
R&D contracted out to public research institution	20	42
Joint research project	30	60

finding in this context, is the high rating given to informal contacts to public researchers.This indicates the importance of informal networks facilitating exchange of tacit knowledge by means of face-to-face interaction.

4.6. Formal knowledge infrastructure

In addition to the interplay between firms and other private organisations, national innovation systems are characterised by specific institutional infrastructures for promoting technology. For example, private institutions include industry associations, branch research institutes, training centres. Public institutions include universities, standard setting organisations, patent offices, research institute systems. This infrastructure is not only different across countries in its institutional set-up; even the single institutions vary with respect to their structure, tasks, financing, and other aspects.

A division of the knowledge system in Denmark is usually done in three groups:

- universities and other higher education institutions;
- sectoral research institutes;
- Certified Research and Technology Organisations (CRTOs) and the

Technological Information Centres (TICs).

These subsystems form the bulk of the Danish technological infrastructure. All three of them are important parts of the Danish NIS-system, but they differ in important respects. Thus, there are differences in how close the activities of institutions within the subsystems are related to firms. The primary task of universities is basic research with few direct links to firms, whereas the purpose of CRTOs directly aims at at servicing the needs of firms. Sectoral research institutes are in an intermediate position in between these extremes. The formal division of labour is sharp as compared to similar structures in other countries, but in practise there are of course overlapping activities.

Due to the special distribution of firms on different size groups in Denmark, i.e. relatively many small and medium sized firms (dominance of specialised suppliers and supplier dominated firms), the technological infrastructure is particularly important in Denmark. The infrastructure is primarily aimed at supporting small firms. However, there are also some formalised institutions aimed at increasing the interaction between universities and science-based industry in Denmark, namely the science parks.[30] Thus, the first part of this section will describe and discuss science parks in Denmark, while the latter part of the section is devoted to the technological service system.

4.6.1. Science Parks

There are five science parks in Denmark, connected to Denmark's six universities. Four of them are directly connected to a single university (Copenhagen, Aarhus Aalborg and Odense), while the fifth, *CAT*, is now connected to Risø National Laboratory, Roskilde University and Denmark's Technical University. They are all rather new. The oldest ones (Copenhagen and Aarhus) were established in 1986, and followed by Aalborg in 1989, Roskilde in 1991 and Odense in 1992. Only one of them has a venture capital fund and a development company of its own. The science parks are very different from each other in terms of economic

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[30] In this context it should be noted that there are no university-industry research centres in Denmark, as defined by the OECD (1995, p. 11). The OECD definition concerns 'mixed laboratories' where university researchers can obtain academic credit for published contributions to technology, and industrial researchers can carry out regular investment in university training. An example of such an institution is Fraunhofer Society in Germany.

and organisational structure, although they have got some common characteristics.

Danish science parks are still rather small. There are now (1995) 64 firms and 300 persons, working on campus in the Copenhagen Park *(Symbion)* and 44 firms and 275 persons in the Aarhus park. Aalborg (*NOVI*) has 32 firms and 230[31] persons, Odense has 18 firms and 100 persons and Roskilde (*CAT*) has 22 firms and 80 persons in its science park.

As mentioned in the introduction to this sub-section, the services provided differ between the science parks. All parks provide different kind of administrative assistance, but some parks, like *NOVI* and *CAT*, also emphasise an effort to assist in providing (personal) contact between researchers at the universities and in business firms, and is in that context attempting to identify areas of interaction, while e.g. *Symbion* does not provide such activities.

Financially, the parks are only marginally supported by the government. Recently, however, local and regional government have been given legal possibilities to establish and support science parks. To a large extent the establishment of the Danish science parks has been financed by private funding, and the parks are all earning their main income from rents payed (for housing and different kinds of assistance) by the firms present in the parks. The *NOVI* park has got the advantage of being located in an area entitled to EU regional support. Partly because of this, *NOVI* is the only science park, which can provide financial assistance (venture capital) both in relation to start-ups, but also to already existing firms, setting up new projects.

The over-all sectoral distribution is broad but with a dominance of advanced parts of the local knowledge base. It is also quite clear that the projects of the science parks are concentrated in areas in which the university in question has a strong competence. In Copenhagen, research on biotechnology and IT (mainly software development in relation to computer networks) dominates. In Aalborg electronics (including fishing equipment) dominates, with a particular presence of mobile communication equipment; in Aarhus there are many biotechnology projects and in Roskilde the projects seem to be concentrated in optical technology and renewable energy, while Odense seems - at least to some extent - to have a particular strength in software. A prominent example of software developed in the park, is software for the use in advanced robotics, produced as a result of

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[31] Including approximately 100 engineers conducting research for the Korean mobile telephony company Maxon.

Denmark's most advanced shipyard, *Lindø*[32], having activities in the *Science Park Odense*.

The differences in terms of specialisation also reflect differences in the structure of Danish Universities. Only Aalborg University (of the full universities) has got activities in engineering (training at MSc and PhD level). But also the *CAT* science park has got a more vocational science-base, since it is not only connected to Roskilde University, but also (and probably more important) to *Risø*[33], and more recently has been connected to Denmark's Technical University (*DTU*) in Copenhagen. Risø is a government enterprise under the Danish Ministry of Research and Technology. Risø performs scientific and technological research and the objective of the research is to strengthen the technological development in three main fields - energy technology/energy planning, environmental aspects of industry/energy and cultivation of plants, as well as materials and measuring technology for industrial purposes. The only other Danish university in engineering, namely *DTU* has not got a science park directly attached to it, but became connected to the *CAT* science park in the middle of 1995. In this context, the aim of *CAT* is to strengthen its competence in electronics, building on capabilities, present at *DTU*. Thus, given the structure of the Danish science system, it is not surprising that more fundamental sciences, which also have potential technological application (molecular biology, chemistry and computer science), come to dominate in the two oldest parks, namely the *Science Park Aarhus* and *Symbion* in Copenhagen.

Science parks has not been a priority area in Danish policy even if their potential import ance is recognised in government reports on industrial and innovation policies. The economic conditions for Danish science parks are relatively poor compared to other countries and the connections between science parks and the rest of the total system for government support of industrial development is weak (Ministry of Industry, 1996, p. 228). It would probably be fair to say that Danish policy has emphasised 'the technological service system' (section 4.6.2 below) much more than on science parks.

In a recent report, the Ministry of Industry argues that the Danish science parks have produced good results and have attracted many researchers, entrepreneurs and smaller firms. However, the Ministry states that the parks have not yet led to

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[32] Owned by the large international shipping firm *A.P. Møller*

[33] The science park is located on the site of Risø's, situated approximately 10 kilometres from Roskilde University. In Denmark Risø is well-known, because it has been Denmark's centre for nuclear research, since established in 1958. Risø has got Denmark's only (research) nuclear reactor.

the establishment of new innovative firms, to the same extent as in other countries. Whether this is due to the relative novelty of science parks in Denmark, or whether it is due to other factors, such as the limited economic resources allocated to the parks, is not clear.

Overall, it is obvious that the science parks - given the small size - do not constitute a quantitatively large influx of knowledge into the Danish business sector. Nevertheless, the science parks might play a larger role than suggested by the relatively small numbers of firms engaged and researchers employed on the campuses. Firstly, the firms are not allowed to have production in the science parks; thus some firms have got production and research elsewhere as well. Secondly, since the firms in the science parks are to a large extent ‘science-based’ in the Pavitt sense, the firms are likely to be connected to firms in other sectors, via user-producer interaction, thereby further diffusing knowledge down (or up) the value adding chain. Thirdly, the importance of the science parks might not reside in their present size, but as a possible engine of industrial growth in the (uncertain) future. Thus, a majority of the results of applied science (even) might not end up, having any useful commercial application. But on the other hand, if an invention seems to be insignificant, and later on turn out to be important, it might be to late to ‘catch up’ if no competence is present at all. Given such a view, the most important role of the science parks might be looked upon as being the national equivalent to ‘keeping doors open to an uncertain future’, also known in the literature on corporate strategy, as increasing option values (Mitchell and Hamilton, 1988). However, more research is requested in order to understand better (and evaluate), how important such a wider impact, described above, is in the Danish case.

4.6.2. The technological service system

In the rest of this section the analysis is narrowed down to focus upon the core of the Danish infrastructure on advice to innovation and technological services, namely CRTOs and TICs. This system is firstly described, secondly evaluated, and thirdly a short discussion is included on the future strategy and challenges for this system.In this context, it will be made clear what are the best data sources for assessing and analysing the system.

The *purpose* of the system is smoothly and rapidly to provide firms with useful knowledge on e.g. new technologies, and to help firms utilise new knowledge.

Table 16: Key figures for CRTOs 1994.

Institute	Employed	Turn-over [mio.dkr]	Funding [mio.dkr]
Biotechnological Institute	144	75	15.7
Danish Institute of Fire Technology	78	41	3.2
Danish Design Centre	14	13	9.3
Danish Hydraulic Institute	198	161	5.8
Danish Institute of Fundamental Metrology, DEM	13	11	9.3
Danish Standards Association	141	104	15.3
Danish Technological Institute	1066	688	99.7
The Danish Toxicology Centre	28	13	0.0
DELTA Danish Electronics, Light & Acoustics	191	113	15.5
DIFTA - Danish Institute for Fisheries Technology and Aquaculture	49	27	4.2
dk-Teknik	136	67	1.9
FORCE Institute	767	392	20.7
Danish Maritime Institute	78	42	4.2
VKI Water Quality Institute	150	99	2.9

CRTOs

Thus, the institutes have a three-step function in relation to the increase of the knowledge base in firms: discovering, diffusion and implementation. In particular these functions are important in relation to SMEs. To make specialised technological knowledge accessible for firms involves both advising, testing, training and research. As there in Denmark is no system of sector specific research institutes (even though most institutes are in practice targeted at specific sectors), the CRTOs also assist specific sectors in their use and diffusion of new technologies.

Similar systems exist in other countries. As compared to other countries the Danish system dates further back in history. For example, the Danish Technological Institute was established in 1906.

The system is constituted by a number of independent institutes which - if certified - receive some basic funding from the government but apart from this operate on a commercial basis - i.e. sales of services to firms and public institutions. The government part of the funding is especially aimed at co-financing the build-up of internal competencies, development of new kinds of services, participation in standard-setting activities and general diffusion activities.

Certification is done by the Minister of Industry on the basis of recommendations from The Industry and Trade Council. They are certified for a 3 year period of time. At present 14 institutes are certified. The number of certified institutes has decreased from 60 in the past 6-7 years, through a number of mergers. The institutes are diverse both in terms of size, structure and profile. Table 16 shows some key figures for the institutes certified today. Appendix table A2 gives a detailed description of the profile of each institute. The Industry and Trade Development Council assesses annual reports on the performance and the future strategy of the institutes and decides on the size of co-financing. The practical implementation of the politics towards the CRTOs is done by The Danish Agency for Trade and Industry.

A common organisation for all the CRTOs has been established in 1995 - the Advanced Technology Group. This is the forum for discussion with the public on the role and function of the CRTOs as well as on certain R&D-programmes initiated in the EU.

The Technological Information Centres

The technological Information Centres (TICs) are regionally based centres for non-specific advice to SMEs within especially technological but also management issues. In recent years also areas like quality control and environment has been on the agenda in many of the contacts to firms.

In total 15 TICs are spread around the country, one in each county, but two in North Jutland. They are relatively small units with an average staff of 4-6 consultants employed on a full-time basis, and in addition 1-2 secretarial employees. In total there are around 100 employeees in the TIC system.

One of the primary tasks of a TIC is not only to give the first, non-specialised advice to firms, but also to provide advice to the single firm as to what needs the firm has for *further*, specialised advice. In addition, the TIC advices firms on where to buy this specialised expertise. Also government programmes are channelled through TIC. In this manner, TICs can be seen as being in a position between the firms and the specialised competencies in the CRTOs. This intermediary function is rooted both in the regional base and in the knowledge of the TICs about where the relevant competencies are. This knowledge is difficult for firms to acquire themselves - especially in the case of SMEs.

An effort has been initiated to enhance the role of TICs as intermediaries between firms and the advisory system. Furthermore, the profile of the TICs is broadened to include to a larger extent the advice on issues like market development, strategic planning and immaterial investments.

4.6.3. Evaluation of CRTOs

The criteria for an efficient advisory and knowledge diffusion system is:

- effective distribution of the relevant information and advice;
- high and relevant competencies;
- transparency and easy access;
- effective control and use of resources.

The overall structure of the Danish system has been evaluated as adequate.[34] However, the strengths of the different parts of the system could be enhanced if collaboration between elements in the system could be increased. In an international comparison the total amount of resources in the Danish system is relatively sparse, but could be used more effectively if internal links between elements in the system are reinforced. Therefore, incentives for increasing this collaboration has recently been introduced.

The relative high share of the total turn-over in CRTOs (68%) which is payment from external clients indicate that the services and competencies in CRTOs are highly relevant to firms. More than 20.000 firms are in contact with the system on an annual basis. Furthermore, many of the CRTOs have a relatively high share of the turn-over from international customers (one 56%, another three 35-38%). Also the OECD evaluation points out that the quality of services and competencies within CRTOs are high.

With respect to the access to the system it has been argued that the relatively high costs of the services offered by CRTOs keep SMEs from using the system as much as would have been beneficial to them. A government subsidy to the costs has

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[34] Evaluation of the Danish science, technology and innovation system by the OECD (1994) plus an evaluation by the customers and the institutions themselves by the Vilstrup Institute.

been tried (the programme ended in 1989). The evaluation of this step is both positive and negative. On the positive side it made firms use the CRTOs more, especially small firms. A side effect is that it made the firms appreciate external advice in general, and made them use other parts of the knowledge system as well. On the negative side, expectations to the quality of the consultancy was down graded due to the low price after subsidy. This change in expectations took place with both the supplier and buyer of the service. This was to some extent damaging for the overall CRTO system. Nevertheless, it has not been given up to invent some kind of government subsidy of the costs.

A thorough evaluation of the CRTO system was conducted in the autumn 1994. As a part of this evaluation 2016 firms were interviewed on their assessment of the system. On the basis of these interviews a database was constructed. Although other data sources like e.g. CIS data include the role of CRTOs this database is the most adequate for analysing CRTOs in Denmark. Some of the most important results from the survey are that users of the CRTOs and TICs are generally positive. This goes for the assessment of

- ability to assist the firm when this has a lack of knowledge;
- ability to increase the competencies of the firm;
- the standard of the institutes in comparison with similar institutions abroad;
- the degree to which the institutes are service-minded;
- the way the advice from the institutes supplement other parts of the advisory system.

Generally, the firms found the services to expensive. Answers to a question on the general importance of CRTOs and TIC for Danish firms show that

51% see their importance as very large;
23% see them as having some importance;
4% of little impact;
3% of close to no impact;
19% do not know.

4.6.4. Future Strategy

It is expected that innovation will be an even more important strategic factor in the future international competition. This will in itself increase demand for competent advisory services. In other words there is a need for the advisory system to be innovative and take the challenge of increased innovation and increased input of knowledge in production. This challenge is met by the Danish system by way of several objectives for the future development of the system. These objectives are listed by the Industry and Trade Development Council as:

- to increase the strategic interplay between firms CRTOs and research institutions;
- to provide incentives for universities, sectoral research institutes and CRTOs to mutually direct costumers to each other when appropriate for the costumer;
- to make the system more visible for potential costumers;
- to see to that SMEs have easy access to the adequate competencies in the system;
- to implement an internationalisation strategy for the single institutes and for the system as a whole;
- to increase mobility and exchange of employees between different parts of the advisory and research system as a whole. E.g. between universities and CRTOs;
- to increase the use of synergies between competencies within different institutions.

The implementation of these strategies is a major challenge for Danish politics in this field. A first step has been to increase the government funding of both CRTOs and TIC, but also organisational changes on the political level is considered.

4.7. Knowledge flows in connection with the labour market

An important carrier of knowledge, is flows via the labour market, given that knowledge is to a considerable extent embodied in persons. Thus, this type of knowledge flow is particularly important for intra-sector flows of knowledge, since knowledge accumulated in firms (or public institutions) is to a large extent specific to the sector. One way of analysing this type of flows is by the large Danish labour market database *IDA*, mentioned above. IDA is a Danish acronym for ‘integrated database for labour market research’ (Integreret Database for Arbejdsmarkedsforskning), and contains data on *every* person present in Danish labour market, from 1980 onwards (most recent year is currently 1992). The database is maintained by Statistics Denmark. One reason for why this database is a valuable source of information, is that it contains data on sector of employment (including being a student) and level of education. Therefore, the database makes it possible to measure personal mobility across sectors and between universities and sectors in the economy, over time. For instance, it is possible to measure the number of engineers moving between firms intra-sectorally, as well as inter-sectorally, resulting in a kind of input-output matrix for labour. A more advanced kind of analysis would be to measure the flow of more than one type of labour, by attributing weights to the specific types of labour. Such an approach might be useful, given that different types of labour are likely to transfer knowledge at different rates. Another possibility would be to analyse where PhD students in engineering and natural sciences are employed subsequently, in the business sector, thereby quantifying one important aspect of university-industry relations. Sweden and Norway have got similar labour market data. Therefore, it could be interesting and valuable to NIS research, to make a Nordic comparison along the dimensions briefly presented in this section.

4.8. Four Danish case studies

This section describes some important linkages, in four different sectors in which Denmark is strongly specialised (see Dalum, 1996), facilitating distribution of knowledge within the innovation system. One reason for pursuing this exercise is that the OECD-outline mentions the need for qualitative evidence on interaction in various NIS'. The section serves the purpose of illustrating the differentiated nature of the knowledge base in manufacturing, and in this context the differentiated importance of the specific knowledge across sectors. Thus, this section will make the attempt to demonstrate, that rather detailed and more qualitative studies are required in order to understand how knowledge is distributed into (and in) specific sectors. The section will briefly describe creation and distribution of knowledge in one supplier dominated sector (furniture), two specialised supplier sectors (producers dairy equipment, electro-medical instruments), and a science-based sector (pharmaceuticals).

Producers dairy equipment (and manufacturers of milk products)

A well researched area is the Danish 'agro-industrial' complex. This complex is described in general terms by Andersen (1981) to illustrate the importance of the home market for international trade specialisation. A particular part of the complex is 'the dairy vertical', further analysed by Lundvall *et al*. (1984). An important part of the vertical consists of the linkage between users of dairy equipment (large Danish dairies) and manufacturers of machinery for the use in this sector. In the ISIC nomenclature, dairy export belong to the food, drink and tobacco sector, whereas dairy equipment is included in non-electrical machinery;

two sectors in which Denmark is heavily specialised. Thus, an important part of the knowledge base of these sectors is built in the interaction between the two, thereby resulting in a co-evolution between the sectors, which tends to produce international competitiveness in both fields.

Electro-medical instruments

The ISIC sector instruments, is one in which Denmark is specialised in terms of R&D expenditure and where Denmark has a higher R&D intensity as compared to the OECD9 (see section 3.7 above). Lotz (1990) demonstrates the historical importance of the interaction between medical instruments and an advanced domestic hospital sector. One example of the importance of the interaction is the most successful Danish firms in this area, namely Radiometer, where internal R&D conducted since 1935 has provided a basis for a close interaction with Danish hospitals, especially Rigshospitalet (the State University Hospital) in Copenhagen. Thus, one of the major innovations (apparatus for measuring the level of pCO2 in the blood) for this company was actually invented by a head of department of clinical chemistry at Rigshospitalet in the early fifties, but transformed into an innovation at Radiometer. Today, the interaction with hospitals (especially in the Copenhagen area) continues, in order to maintain competitiveness by means of distributing user- knowledge from hospitals to specialised suppliers in the instrument sector.

Furniture

Wood, cork and furniture, is another sector where Denmark is specialised, in terms of value added (see figure 5), but with a lower level of R&D intensity, compared to other OECD countries. In other words, the sector seems to be competitive, although it has a comparatively low R&D intensity.This apparent paradox is explored by Maskell (1996). The wooden furniture production consists of two distinctive and technologically distinct processes - the process of manufacturing the furniture (wood cutting, drilling, shaping, grinding and shaping), and the process of painting it (the entire coating process including smoothing, painting or lacquering, priming, drying/defueming, polishing etc.). In contrast to the Danish agro-industrial complex, the exchange (distribution) of knowledge is not conducted by means of the development of capital equipment for the former process, since today 90% of the machinery is imported, mainly from Germany and Italy. The same goes for the machinery for painting (mainly imported from Italy). But while the industry works with a more or less given process technologies, a part of the manufacturing process which can be ‘moulded’ or adapted as to give a leading edge, and this includes the lacquer and paints, which is adapted in the interaction with domestic manufacturers. Another important contribution to the knowledge-base comes from an *agglomeration effect*, and reflects that local and specialised educational institutions play an important role, together with the (local) mobility in the labour market.

Pharmaceuticals

One of the few science-based sectors strongly present in Denmark is the pharmaceutical sector. In terms of growth in Danish share of OECD9 R&D from 1980 to 1991, the pharmaceuticals sector accounted for nearly 50% of the total Danish growth (table 7), and from a more static point of view the sector accounted for as much as 24% of total Danish R&D in 1991 (table 2). By far the largest Danish producer in this sector is the worlds largest manufacturer of insulin for diabetics Novo Nordisk (Laursen, 1995). The company's history goes back to early this century. From a historical point of view, it is remarkable that the breakthoughs in terms of new and radically better insulin products have been conducted inside the firms R&D department, although often in collaboration with foreign scientists (mainly American). Thus, largely firm-specific knowledge has been accumulated over nearly 3/4 of century, where the technological linkages (dynamic synergy effects) between different products has been an essential feature. Nevertheless, one has to point out the importance of the presence of a strong national science-base. A particularly strong Danish science-base can be identified, in this context, if measured by number of published papers pr. capita in life-sciences, where the number of papers published was about 20% higher than the US figure, and about 70 higher than an EU10 average in the period 1981-1986. But Denmark ranks high generally speaking, in all of the major science fields in addition to life-sciences (mathematics, physical sciences, engineering and chemistry), both in terms of papers pr citizen, and measured as mean citation pr. paper.

Even though basic research tends to become globally accessible, since it has a strong public good element, this is not the full agenda. Recent research by Hicks *et al.* (1994) has showed that publications produced by Japanese companies (basic research) tend to over-cite the national science system by approximately 30%, which in turn suggests that the economic benefits are geographically and linguistically localised, since they are embodied in persons and institutions, and thus mainly transmitted through personal contacts. Similar findings have been made by Narin and Olivastro (1992) showing that national patents cite national science and vice-versa. A strong position in basic research is therefore economically important at the national level, because it provides research training, state-of-the-art development and use of research techniques and instrumentation, and access to high-quality international networks (Gibbons and Johnston, 1974, Pavitt, 1993). In addition, basic research provides an important country-specific ressource to science-based firms, providing recent results from national as well as international state-of-the-art-research as an input to commercial research. These benefits accrue, not only because of the research conducted by the scientists of a given country, but (mainly; at least in a small country case) because of the increased ability to assimilate results of basic research conducted by other countries, an ability which in turn partly depends on the home country's ability to perform high quality basic research itself. In the Novo Nordisk case major break-throughs was nearly always taking place at foreign universities. In this context, the *research skills,* developed at Danish universities have been of utmost importance in assimilating and commercialising inventions made abroad. In the context of *state-of-the-art development and use of research techniques and instrumentation*, comprehensive mathematical molecular models, should be mentioned. Another potential impact of basic research was found in many cases, through the entire history of Novo, namely the *ready access to high-quality international scientific networks*, a story which began with Nobel Prize winner and originator of insulin production in Denmark, August Krogh in 1923, ending up with current contacts to 'centres of excellence' in biotechnology, situated in California.

Thus, a continued commitment to basic research is of central importance to the competitiveness of this sector. So far, little research has been conducted applying (at a detailed level) bibliometric methods, in order to access the continued viability of the science-base in the Danish system.

Knowledge bases

This section has shown how the nature of connectivity of a NIS, differ between sectors and development blocks. Table 17 illuminate some of these differences, and serves to illustrate that the important knowledge base of sectors in a systems may well reside in the interaction with other parts of the system. The main point is that the *strategic point of connection* between the parts of the system is not known *a priori*; it is an empirical question where such points are located. The recognition of this, is of course important from a policy point of view, since policies designed at increasing the general interconnectivity in the NIS, might well be wrongly designed if only specific interactions are considered (e.g. university-industry relations).

Table 17: The most important knowledge bases for four particularly strong Danish sectors.

Sector	Important external knowledge bases (interaction with)	Level of cumulativeness in R&D	Importance of scientific knowledge	Importance of technological service systems
Domestic producers of milk processing machinery	Producers of milk products	medium	low*	some
Furniture	Domestic producers of laquer and paint	low	low	some
Medical instruments	Domestic hospitals	high	some	-
Pharmaceuticals	National and international science-bases	high	high	-

*) The potential importance of scientific knowledge in this sector might be high (e.g. the use of biotechnology), but so far it has continued to be *relatively* low.

4.9. Summing up on the measurement of interactivity in the Danish innovation system

This chapter has had the purpose of elaborating on possibilities of measurement of various knowledge flows in Danish innovation system, even though some results were presented as well.

Firstly, various feasible methods of measuring embodied knowledge flows were presented and discussed. It was shown that such flows can be measured by means of input-output tables on the one hand and ANBERD data, CIS data or IDA labour market data on the other hand.

Secondly, analytical possibilities using CIS, and also to a smaller extent PACE data in order to analyse and describe user-producer co-operation and R&D collaboration, were considered. It was clearly seen that market factors play an important role in this context (and significantly more so than the ‘technology factors’). However, it was stressed that the data says nothing about what is the important factor in *carrying out* the innovation. Furthermore, it was also shown that the most important means of purchasing technology by Danish firms was purchase of equipment from - and communication with - other firms. This is also compatible with a hypothesis of user-producer relationships being important in the innovation process, especially when it comes to *external* linkages.

Concerning research co-operation it was demonstrated that 30 - 60 % (depending on size) of the Danish firms, who conduct research and development are involved in research co-operation. In terms of collaboration with the public research system it was demonstrated that the most important factor was the informal contacts to public researchers.

Thirdly, a discussion of the impact of formal institutions for promoting the creation and distribution of knowledge was conducted in section 4.6. Concerning science parks it is clear that the Danish parks are small as compared to the parks of other countries, and that they have not (yet) become a major engine for setting up new innovative firms, to the same extent as in other countries. However, it was argued that an assesment of the direct impact from the existence of the science parks should be supplemented by taking into account 1) linkages to other firms by firms located in the parks; 2) the ability to keep windows of opportunity open to new fields with an uncertain future.

When it comes to the technological service system the system was described, and it was argued that this part of the innovation system is probably more important in Denmark, compared to most OECD countries, given the existence of many SMEs (supplier dominated and specialised suppliers). In Denmark, a combination of two types of institutions complement each other in creating and diffusing knowledge, namely the CRTOs and the TICs. Even though the amount of resources allocated to the system is relatively sparse, the OECD has concluded that the Danish technological service system is adequate, but could be more efficient if internal links, within the system are reinforced.

Fourthly, possible methods for using Danish labour market data, in the context of measuring flows of personnel were described. In this context there is a lot of opportunity in using the IDA database, which has until now been used by mainly labour economists.

Finally, four Danish case studies were presented as a means of describing some of the interaction in the NIS. What the case-studies demonstrate is that the knowledge-bases differ significantly between sectors, both in terms of where the knowledge-base resides and in terms of the relative importance of knowledge-bases between sectors. One conclusion arising out of this is that interactivity in the NIS is important, but that it is an empirical question, where the most important knowledge-base reside.

5 Conclusions and implications for future research

5.1. Conclusions

This chapter summarises the main findings of this report, in addition to pointing to some possibilities and difficulties in conceptualising and measuring interactivity in NIS. Finally, some of the limitations of this report will be discussed.

In chapter 2, the theoretical framework was discussed and presented, and it was argued that NIS should be analysed in terms of a sectoral approach, given that innovation is a process which is differentiated across sectors. Furthermore, the definition of the system was narrowed down by focussing on institutions directly involved in the creation and distribution of knowledge in a NIS. Likewise it was pointed out that the focus is on the interactivity of the system, and less on aspects of ‘social capability’. In addition five types of knowledge flows were identified, to be used in the empirical chapters (primarily chapter 4). The five flows identified were: Flows embodied in commodities, traded between sectors; flows going through other inter-firm (mainly user-producer) relationships; flows facilitated via university-industry relations; flows facilitated via the interaction between other (other than university) public institutions and business firms; and flows embodied in people (personal mobility).

Chapter 3 described the Danish business sector in terms of sectoral distribution. In this context some areas of specialisation were identified. An interesting aspect of the Danish system is that an area which is not so well researched, namely services, accounted for more than 25% of total Danish R&D in 1991. What was not so surprising is Denmark’s specialisation in food, drink and tobacco; pharmaceuticals; non-electrical machinery; and instruments, and under specialisation in automobiles; aerospace; and information technology, generally.

Such relative strengths and weaknesses were the same whether measured as value added, production, employment or R&D.

Furthermore an attempt was made to asses whether the low R&D intensity in Danish manufacturing industry is caused by a disadvantageous sectoral specialisation. It was shown that this is to some extent the case. However, if firms in a NIS are not able to conduct meaningful technological search in technologically unrelated areas, because of the path dependent nature of technological change, enhanced durable user-producer interaction and so on, it is not meaningful to conclude that Denmark should dramatically change sectoral specialisation because the sectors in which the country is specialised, appear to offer generally low growth in technological opportunity. Given such rigidities, Denmark will not, in the foreseeable future, get a (real) R&D intensity at the *level* of the OECD9. However, this not to say that the Danish system is performing well in terms of R&D performance. It remains a fact that Denmark's R&D intensity is significantly below the OECD9 average. What might be worrying is that not more resources are allocated to R&D in 'medium' or 'low tech.' sectors in Denmark, since more resources should be available for conducting research in these sectors, given that Danish firms in 'high tech.' sectors are using considerably less resources compared to what is used by the same sectors in other countries. This is so since the relative size of these 'high tech.' sectors are smaller in Denmark (except from pharmaceuticals), when compared to the majority of advanced countries. Thus, given that Danish firms are relatively (very) competitive in non-electrical machinery and food, drink & tobacco it is particularly worrying that these sectors are not conducting significantly more R&D pr. value added than do the OECD9. Moreover, it is worrying that Danish firms are generally conducting less R&D in 'low tech.' (> 3.5 R&D intensity), compared to the OECD9, since Danish firms in only three out of ten 'low tech.' sectors are conducting significantly more R&D than does the OECD9 average.[35]

From a dynamic perspective, it is encouraging that Danish firms tends to conduct a larger share of OECD9 R&D in the period 1980 to 1991. However, it should be noted that the gain is not coming from the whole business part of the NIS; the gain is largely due to an increase in R&D expenditures in only three sectors, out of 22 (pharmaceuticals; non-electrical machinery; and instruments).

Chapter 4 looked into the interaction in the Danish NIS, structured according to the types of knowledge flows described in the beginning of this chapter (and discussed in chapter 2). First, various feasible methods of measuring embodied

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[35] However, it should be pointed out again that since R&D is not the most important factor for competitiveness in 'low tech.', R&D data might be less reliable for these sectors.

knowledge flows were presented and discussed. Accordingly, such flows can be measured by means of input-output tables on the one hand and ANBERD data, CIS data or IDA labour market data on the other hand.

Secondly, analytical possibilities using CIS and also to a smaller extent PACE data in order to analyse and describe user-producer co-operation and R&D collaboration, were considered. It was shown that market factors play an important role in this context (and significantly more so than the 'technology factors'). However, it was stressed that the data say nothing about what is the important factor in *carrying out* the innovation.

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Finally, four Danish case studies were presented as a means of describing some of the interaction in the NIS. What the case-studies demonstrate is that the knowledge-bases differ significantly, between sectors, both in terms of where the knowledge-base resides and in terms of the relative importance of knowledge-bases between sectors. One conclusion arising out of this is that interactivity in the NIS is important, but that it is an empirical question where the most important knowledge-base actually reside.

5.2. Implications for future research

This report has made an attempt to describe and analyse the Danish NIS, primarily using the quantitative data available, in addition to outlining possible areas of future empirical research. However, one weakness of the report is that the chapter on interaction (chapter 4) in the system contains few international comparisons. That is, we do not know whether specific statistical figures are relatively large or small. Such comparisons are urgently needed.

In addition the study contains almost no analysis conducted at the firm level, which is also needed since technological knowledge is mainly created within business firms, but with some contribution from external sources. Thus studies on NIS will benefit from adding this level of analysis. This is especially the case for science-based firms, where the cumulative mastery of core technologies inside business firms is very important. But it should be stressed that firm-specific competencies are important for all types of firms.

The OECD framework also ask for estimations on performance in direct relation to the strength of a systems ‘distribution power’. However, this relationship is an extremely complex one, since performance indicators such as economic growth and trade performance are multi faceted variables, which depend on a range of (interlinked) variables. Likewise, if knowledge is distributed by means of interactive learning between users and producers it is likely that new (specific) knowledge is going to be created, in such a way that it cannot meaningfully be distinguished from knowledge distributed to a given sector. In addition one should take into account that countries are specialised in different sectors. Thus, if correlations were to be conducted on ‘distribution power variables’ and performance indicators, one would have to be sure that the level of interactivity is simply not reflecting that countries are differently specialised, since some types of firms have got more external linkages than other firms does.

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Appendix table A1: R&D intensity among nine OECD countries and OECD9. R&D divided by value added per sector (1991).

No.	Sector	OECD9	CAN	DEU	DNK	FIN	FRA	GBR	ITA	JPN	USA	VALUDIST (OECD)
1	Food. drink and tobacco	1.13	0.47	0.41	1.40	2.36	0.94	0.81	0.27	1.76	1.35	11.44
2	Textiles. footwear and leather	0.59	0.76	0.54	0.43	0.91	0.40	0.28	0.05	1.74	0.45	5.60
3	Wood. cork and furniture	0.41	0.66	0.61	0.26	0.71	0.18	0.12	0.04	0.73	0.37	4.05
4	Paper and printing	0.61	0.75	0.27	0.23	2.00	0.27	0.35	0.01	0.92	0.63	9.13
5	Industrial chemicals	9.76	2.38	11.38	3.47	10.60	8.59	11.81	3.56	12.32	8.01	7.01
6	Pharmaceuticals	22.88	11.64	19.22	30.31	25.97	29.68	44.46	22.36	17.24	20.04	2.23
7	Petroleum refineries	6.10	9.91	0.76	0	7.87	2.39	5.99	3.65	11.87	10.45	2.05
8	Rubber and plastics	2.71	0.53	2.21	1.19	4.23	4.17	1.26	1.48	4.48	2.07	3.92
9	Stone. clay and glass	2.54	0.50	1.54	1.95	2.98	1.59	0.91	0.18	4.75	3.60	3.66
10	Ferrous metals	2.21	0.68	1.09	3.19	3.04	2.34	1.74	1.14	4.20	0.82	3.99
11	Non-ferrous metals	3.73	4.88	1.09	8.80	5.38	2.51	3.18	3.52	5.90	3.48	1.70
12	Fabricated metal products	1.27	0.65	1.66	0.95	1.84	0.79	0.93	0.55	1.77	1.21	7.06
13	Non-electrical machinery	4.86	1.38	6.27	4.52	7.16	3.87	3.25	2.38	7.06	3.77	8.46
14	Office machines and computers	26.17	29.52	13.79	16.18	16.81	10.03	19.14	19.49	19.69	37.60	2.77
15	Electrical machinery	8.44	1.95	9.13	6.65	11.06	4.00	7.49	5.87	12.46	5.34	4.35
16	Communication equipment and semiconductors	20.61	28.86	16.47	14.49	25.91	32.31	25.45	14.93	13.23	26.54	6.34
17	Shipbuilding	1.13	0.37	2.62	3.46	3.53	1.27	0.67	4.59	1.71	0	0.61
18	Other transport	9.07	19.33	3.35	3.57	5.31	5.28	0	3.49	4.55	23.06	0.32
19	Motor vehicles	12.61	0.65	10.10	0	4.57	10.21	8.57	10.69	11.71	18.92	7.11
20	Aerospace	45.55	15.58	61.39	0	4.31	53.17	24.12	29.30	29.10	49.67	2.73
21	Instruments	10.55	0.00	4.78	18.65	15.56	3.98	2.50	2.22	16.89	11.94	3.08
22	Other manufacturing industries	1.57	0.93	1.08	13.36	2.42	0.92	1.03	0.27	1.28	2.44	2.39

Source: STAN/ANBERD (OECD)

Appendix table A2: Variables in the CIS questionnaire

Group of variable	Examples of variables/sub-groups of variables	Type of variable
General information	Number of employees, Turnover in 1992 and 1990, innovative - non-innovative	metric, binary
Sources of information for innovation	Internal sources, external-/market sources, educational-/research establishment, Generally available information.	Ordinal
Objectives of innovation	Replace products, extend products, new markets, lower production costs	Ordinal
Acquisition/transfer of technology	Licences, consultants, purchase/sale of equipment, skilled employees, R&D, communication with other enterprises. All variables broken down on geographi	Binary
Appropriability	patents, design, secrecy, lead time advanteges, complexity	Binary
R&D Activity	Expenditure internal and external R&D, plans for R&D, cooperation with different partners broken down on geographi	Binary, metric
Factors hampering innovation	economic factors, enterprise factors,	Ordinal
Costs of innovation	current expenditures - broken down on R&D, acq. of patents and licences, product design, trial production, market analysis, capital expenditures,	Metric
Impact of innovation activities	distribution of sales on product stage, degree of change of products, export sales, products new to the industry	Metric

Appendix table A3: Variables in the PACE questionnaire

Group of variable	Examples of variables/sub-groups of variables	Type of variable
General information	Number of employees, Turnover in 1992 and 1990, innovative - non-innovative	metric, binary
Sources of information for innovation	Internal sources/parent firms, external-/market sources, educational-/research establishment, public conferences, joint ventures	Ordinal
Appropriability	patents, design, secrecy, lead time advanteges, complexity	Ordinal
R&D Activity output	use of basic research results, specialised knowledge, instrumentation, prototypes, trained researchers or scientists	Ordinal
Methods of access	publications, conferences, hiring skilled labour, personal contacts, funding R&D, joint R&D	Ordinal
Public policies	procurement policies, subsidies, R&D support, information programmes, co-operation programmes, agencies for accessing international information	Ordinal

Annex I: Description of CRTO's

Biotechnological Institute

The aim of the Biotechnological Institute is through consultancy, testing, training, research and development to serve trade and industry as well as public authorities in the fields of food technology, agro-industrial technology and biotechnology.

Danish Institute of Fire Technology

Danish Institute of Fire Technology is a non-profit making certified technological service institute independent of private interests.
The object of the Institute is to promote active and passive fire protection and to help combat and prevent damage to the environment due to fire.

Danish Design Centre

The aim of the Danish Design Centre is to promote good industrial design and to bridge the gab between the world of industry and the design profession.

Danish Hydraulic Institute

The Danish Hydraulic Institute is a research and c consulting organisation developing and applying advanced methods and technologies within hydraulic and water resources engineering.

Danish Institute of Fundamental Metrology, DEM

The Danish Institute of Fundamental Metrology maintains national primary standards for length, mass, DC electricity and resistance, as well as secondary standard for optical radiometry. Traceability to these standards is provide through accredited calibration in accordance with EN45001

Danish Standards Association

The Danish Standards Association is an independent non-governmental organisation recognised as the central body for standardisation in Denmark. The objectives of the Danish Standards Association are:

- To promote standardisation and certification nationally as well as internationally for the benefit of the Danish society and trade and industry;
- To undertake certification activities, including certification of systems, products and personnel;
- To function as an accredited certification body;
- To disseminate knowledge and information on standardisation and certification.

Danish Technological Institute

Danish Technological Institute, DTI, is a private non-for-profit institute providing services to customers in Danish Industry, with a strong emphasis on SME´s. DTI staff of 1,100 is active in the fields of research and development, constancy, testing and certification, information and training and other technological services.

The Danish Toxicology Centre

The primary objective of the Danish Toxicology Centre (DTC) is to procure, assess and communicate toxicological experience on the hazardous effects of chemical substances. DTC is a self-governing research institute providing independent expert consultancy on toxicological problems.

DELTA Danish Electronics, Light & Acoustics

DELTA is an independent organisation affiliated to the Danish Academy of Technical Sciences /ATV), and approved by the Ministry of Business and Industry to provide services for private enterprises and public authorities. Providing competitive advantage for clients is DELTA´s core business. DELTA develops new solutions, solves problems and supplies information in related areas of technology: Electronics, software technology, light, optics, acoustics, vibrations and noise.

DIFTA - Danish Institute for Fisheries Technology and Aquaculture

DIFTA - Danish Institute for Fisheries Technology and Aquaculture - is a self-governing, international institute carrying out research and development, providing advice and training within the fields of fisheries and aquaculture.

dk-Teknik

dk-TEKNIK is a self-owned independent technological service institutes doing consultancy and R&D within energy and environment analysis, -optimisation, and -management of industrial process and sties.

FORCE Institute

The FORCE Institute is one of Europe's largest independent research and technology institutes, approved by the Danish Ministry of Business and Industry as a technological service institute and affiliated to the Danish Academy of Technical Sciences. Established in 1941 and operating on a non-profit basis, the FORCE Institute provides industry with technical support within the following main fields:

- NDT and information technologies
- Material and product testing
- Control and certification
- Joining process
- Production t technology
- material and surface technology
- Corrosion investigation and protection
- Failure analysis
- Energy and metrology
- Calibration technique
- Chemical analysis
- Biomedical, isotope and sensor techniques
- Quality management and systems
- Systematic maintenance, training and education.

The Danish Geotechnical Institute

The Danish Geotechnical Institute is an independent organisation that provides services within geotechnical and environmental engineering.

Danish Maritime Institute

The Danish Maritime Institute is a private and independent non-profit technological service organisation that offers consultancy services in the fields of hydro- and aerodynamics with special applications in the maritime off-shore, construction, process and energy industries. DMI has provided consultancy services to private companies and public authorities in more than 40 countries.

VKI Water Quality Institute

VKI is an independent research and development constancy organisation affiliated to the Danish Academy of Technical Sciences. Since the establishment in 1972, VKI has provided consultancy services in environmental planning and management of water, waste water, soil, and waste products.