The Danish Government s Knowledge Strategy - knowledge in growth

Background report January 2003

Ministry of Science
Technology and Innovation

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The Danish Governments Knowledge Strategy - Knowledge in Growth

Background report – January 2003

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Preface >

It weighs almost one kilogram, comprises 125 billion nerve cells connected in a network and is available in more than 6.3 billion variations worldwide. The human brain is the centre for the knowledge which shall help secure Denmark's future.

Many factors influence our prosperity, but there is no doubt that Denmark's extensive educational system has resulted in a highly qualified workforce, which is the foundation for Denmark's competitive companies and excellent public institutions.

This focus on education - in all its aspects - must not be lost. However, it is also necessary to seriously consider how knowledge can be converted into growth and prosperity in the Danish knowledge society of the future.

This is why the Government has prepared this knowledge strategy.

In connection with the knowledge strategy, the actual status of four vital driving forces in the knowledge society has been measured: research and development, university education, innovation and IT and telecommunications.

Statistics show that Denmark has excellent potential in the global knowledge economy. We rank highly in most measurements of achievements in the four driving forces. In key areas, however, we are too much of an industrial society and not enough of a knowledge society. We must therefore raise our ambitions to create more interaction between companies and knowledge institutions.

The level of education in Denmark has greatly improved over the last 20 years. As much as 27 per cent of the Danish population has completed a course of higher education, while 18 per cent has initiated a course of higher education. However, internationally, these figures are not as impressive as they should be!

We have too few large and many small and medium-sized knowledge institutions. Compared to international standards, Danish knowledge institutions are not large. However, within their respective fields only a handful of large universities, sector research institutions, hospitals and GTS institutes account for most of the public research, development and knowledge services conducted in Denmark.

Danish companies have mainly focused on development work - and to a lesser extent on basic and applied research. Knowledge-intensive industries make up a small fraction of the Danish business and industry community, which nonetheless has a very high concentration of knowledge. In the private sector, two-thirds of all employees with a university degree (master degree or PhD) are employed by almost 2000 companies - this corresponds to 3 per cent of all Danish companies with five or more employees. Furthermore, collaboration on research, development and innovation between companies and knowledge institutions is far too limited - a condition which the Danish Government intends to change in order to shorten the distance from idea to invoice.

The fact that the number of knowledge-based entrepreneurs is rising and the Danish business and industry community is generally innovative is evidence that we are moving in the right direction. Finally with regard to IT, Denmark's usage of new technology is among the highest in the world. This is true for citizens and public authorities as well as companies.

The Government's knowledge strategy focuses on the development of the Danish knowledge system and comprises several important messages regarding future efforts in the field.

From knowledge to growth. Growth is largely achieved through increased use of knowledge and technology, because in this way we can achieve a more efficient workforce as well as more effective machinery and work processes. We need to become even better at using knowledge and technology to achieve growth in Danish society. As quickly as possible, we need to position relevant knowledge right where it is needed.

One clear goal for the Danish knowledge system. The Danish knowledge system must achieve a position as one of the world's most efficient and competitive. Thus, the interaction with and framework for the knowledge institutions and companies which produce, attract, disseminate and apply research-based and other knowledge in Denmark must be first-rate.

Re-establishment of Danish knowledge investments. With this year's Budget, the Government has allocated funds for further investment in knowledge. The new appropriations more than compensate for the reductions that were otherwise contemplated.

The Government sees expenditure on research, development, innovation and IT as important investments in the future.

Stage 1 - it's time to move on! This knowledge strategy is the first phase of a long haul, which the Danish Government will maintain in coming years. Quick and easy solutions are not often at hand - nor are they in this context.

The focus on the need to invest in the Danish knowledge system must be followed by an effort to ensure that the system works well and can meet society's demands for greater openness and more interaction. Also in this area, the Government has taken the first step by e.g. initiating fundamental reforms of the university and research area. These reforms will now be implemented, and at the same time the Government will launch several new initiatives to strengthen the Danish knowledge system.

Husk underskrift

Helge Sander
Minister for Science, Technology and Innovation
January 2003

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Introduction

In connection with the Government's Policy Statement to the Danish Parliament, "Knowledge in growth - January 2003", the Ministry of Science, Technology and Innovation has prepared this background report. The report consists of two sections:

Part 1: The knowledge strategy

This section is an extended version of the Knowledge Strategy Policy Statement. The knowledge strategy is divided into the following six principal sub-sections:

1. Knowledge in growth - securing the future
2. The knowledge society - new times
3. The knowledge system in Denmark
4. Denmark in the global knowledge economy
5. Action areas in the Government's knowledge strategy
6. The way ahead

The Government's knowledge strategy emphasises a coherent and strengthened effort towards research, education, innovation and IT and telecommunications, which together constitute a significant foundation for a modern knowledge society.

The knowledge strategy identifies six action areas:

1. Reforms of knowledge institutions
2. Competencies and human resources
3. Coherence in appropriations and counselling
4. Interaction between knowledge institutions and the business and industry community
5. Commercialisation of research results
6. IT and telecommunications

The six action areas contain a large number of specific initiatives which have already been initiated or which are to be launched in 2003.

Part 2: Four driving forces in the Danish knowledge society - documentation 2003

"Four driving forces in the Danish knowledge society - documentation 2003" is the documentation material upon which the knowledge strategy is based. It contains, among other things, reviews of articles and publications which depict the views of experts on what creates growth in the knowledge society. Furthermore, it presents key figures on research and development work, university education, innovation, IT and telecommunications. Finally, an analysis of the intensity of knowledge and research in the Danish business and industry community is presented. The documentation report is divided into the following five sub-sections:

1. Introduction and summary
2. Growth in the knowledge society - the expert assessment
3. Four driving forces: a statistical survey
4. Knowledge-intensive companies in Denmark
5. Methodology

The following are the key reports and the data which form the basis for the publication:

Statistics Denmark: IT usage of Danish companies in 2001, IT usage of families in 2002, IT usage in the public sector in 2002, Informationssamfundet Danmark (Information society Denmark) 2001, Firmastatistikken (Company statistics), Uddannelses-statistikken (Education statistics) and Arbejdsmarkeds-statistikken (Labour market statistics).

The Danish Institute for Studies in Research and Research Policy: Erhvervslivets forskning- og udviklingsarbejde (Business and industry's research and development work) 1999 and 2001, Offentlig forskningsstatistik (Public research statistics) 1995-2000, Offentligt forskningsbudget (Public research budget) 2002, Danske virksomheders forsknings-samarbejde (Danish companies' collaborative research) 2002/5 and The European Community Innovation Survey (CIS2 and CIS3).

Danish National IT and Telecom Agency: Udredning om hurtige adgangsveje til internettet (Report on high-speed access to the Internet) - international benchmarking 2002 and Kortlægning af hurtige adgangsveje i Danmark (Survey of high-speed access in Denmark) 2002.

In addition, **Oxford Research A/S** has assisted with the review and analysis of empirical studies on the correlation between knowledge and growth.

Chapter 5 contains a brief description of the key sources as well as the methodological choices made throughout the publication.

Several of these reports and more data are available on the Ministry of Science, Technology and Innovation website: www.vtu.dk or by contacting the Ministry.

Chapter 1 - Knowledge in growth - securing the future >

1.1 Introduction

Knowledge is the key to progress. This was true when our forefathers picked up a stone and used it as a tool for the first time. And this is still true today.

Land, labour and capital create production and thus form the basis for economic growth. A larger workforce and investments in more machinery have played an important role, however, our current prosperity is largely a result of improved knowledge and new technology - thus, leading to a more efficient workforce and more effective machinery as well as work processes.

Knowledge is an expression of our ability to gather and interpret information, gain recognition and achieve proficiencies. With the rapid spread of computers, the Internet and other types of information technology, the amount of available information has increased considerably, as has the potential for converting information into useful knowledge.

No one can say with certainty exactly what future society will bring. However, we currently find ourselves in a situation where new technology provides data and information on a global scale. While at the same time, work with and investments in knowledge have also become more global and mobile.

Four key elements in the knowledge society

> *Knowledge workers are gaining ground.* Internationally, the demand for highly-educated workers is increasing, while the demand for workers with short-cycle training is declining.

> *Research and development is increasing in importance.* More companies are investing in research and development, and the level of knowledge in business and industry is generally on the rise.

> *Innovative networks are expanding.* Companies and knowledge institutions specialise in their own core competencies, while more and more innovations emerge as the result of collaborative initiatives between companies and between companies and knowledge institutions.

> *IT and telecommunication usage is on the rise.* IT is making knowledge development faster and cheaper. The IT infrastructure is spreading rapidly and globally, and IT is becoming increasingly more integrated in communication, administration, products and in the private sphere.

The knowledge society is a knowledge-intensive, international and more complex society where the strongest countries are those who are best at converting knowledge into business and public utility.

In Denmark and large parts of Europe, there is a deeply-rooted understanding of research and education as an open and free asset. This will continue to be the case. However, internationally, developments are turning in the direction of new commercial players entering parts of the knowledge market which were formerly strongly dominated by public institutions. Danish universities already take part in a commercial education market that can be expected to grow even more in coming years.

The market for IT-based distance education is one of the areas with the greatest potential for private universities and education programmes. Correspondingly, IT has created new business opportunities in connection with the communication of research results and inventions. International knowledge and patent databases, for example, provide new and efficient access to knowledge. Some are free of charge, others offer targeted search capabilities for a fee.

Traditional distinctions between the public and the private sectors and between fundamental and commercial research are fading. This applies, for example, to the biotechnology industry where public and private environments are competing side-by-side to produce new scientific break-throughs.

The scientific world has become part of an open market economy where research-based knowledge is disseminated and converted globally on an entirely new scale. For better or worse, Denmark is now faced with this challenge and, technically, nothing stands in the way of, say, a large international university opening its doors in the Ørestad region as a competitor to Danish and Swedish universities.

The knowledge society not only challenges our educational system, it also challenges our research and innovation efforts, IT usage and, ultimately, our companies' abilities to adjust and compete according to these new knowledge-based conditions.

Denmark is one of the most prosperous countries in the world - but we are just a small fragment of the big picture. Fewer than one out of a thousand people in the world is Danish. Our research and development efforts constitute approximately half a per cent on a global scale, and Denmark is not the home base of global driving forces in industry.

All this means that we need to continue to excel at developing and utilising our knowledge system as well as to collaborate with and draw on the results achieved in countries outside Denmark. We need to become even better at acquiring and utilising new knowledge. Research, innovation, IT usage and life-long education should contribute to securing Danish companies and workplaces in an increasingly knowledge-intensive and global labour market.

With this knowledge strategy, the Government submits its vision for how Denmark can strengthen its position as a leader in the knowledge society who increasingly produces, attracts, disseminates and utilises knowledge.

1.2 Investments in knowledge

There are clear financial gains attached to a more intensive use of knowledge. This is important - not least when you bear in mind the fact that the number of Danes of working age is declining. However, the profits should not solely be measured in terms of money. A higher level of knowledge also provides Danes with better jobs and with a greater understanding of a changing world. Finally, more knowledge in conjunction with new technology can contribute to a more efficient public sector.

Investing in knowledge is a cornerstone of the Government's forward-looking growth strategy. Denmark will do its part to fulfil the goal of the so-called Barcelona Declaration of total expenditure on research, development and innovation in the EU approaching 3 per cent of the gross domestic product (GDP) by 2010.

Within this socio-economic framework there must be room for looking forward. The challenges of the knowledge society can be met by making the correct, long-term investments, by securing companies healthy framework and growth conditions and, not least, by reforming the public knowledge institutions. Among other things, this should ensure better utilisation of the knowledge we have at our disposal and greater emphasis on securing profitable investments in knowledge.

1.3 Goals for the Danish knowledge system

The Government's knowledge strategy focuses on the Danish knowledge system, i.e. the knowledge system's interaction with and framework for knowledge institutions and companies which produce, attract, disseminate and apply research-based and other advanced knowledge in Denmark.

Denmark is dependent on having access to new knowledge, which can give the general population new competencies and which can be converted into products and services. As quickly as possible, we need to position knowledge right where it is needed. This means our knowledge system needs to be efficient and competitive.

Knowledge attracts knowledge. Without Danish knowledge production there can be no interaction with the rest of the world. It is, therefore, important to ensure the fundamental conditions for producing qualified and competitive knowledge in collaboration with the rest of the world. This means we need to be able to maintain and attract competent knowledge workers and knowledge-based enterprises. They settle in areas where there are favourable conditions for knowledge environments.

The Danish Government's goal is:

to strengthen the Danish knowledge system's position as one of the world's most efficient and competitive systems.

In this context, the knowledge system consists of knowledge institutions, i.e. universities, government research institutes, university hospitals, Authorised Technological Service Institutes (GTS institutes) and Centres for Higher Education (CVUs) - including engineering colleges, vocational schools/academies and Adult Vocational Training Centres (institutions for industry and business-aimed education). In addition, there are science parks and innovation incubators which assist entrepreneurs and others with the commercialisation of research results. On the corporate side, the knowledge system primarily consists of that part of the Danish business and industry community which produces, attracts, disseminates and applies research-based and other advanced knowledge.

Knowledge institutions provide qualified workers and knowledge to companies. And the interaction between them simultaneously ensures that public knowledge institutions also have access to cutting-edge knowledge developed within such companies. Much knowledge production and innovation in Danish business and industry

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takes place without the direct involvement of public knowledge institutions. However, an improved and closer interaction can undoubtedly provide many companies with better results while providing knowledge institutions with new inspiration.

The knowledge strategy sketches out the guidelines for a healthy interaction between knowledge institutions and the business and industry community. Moreover, this policy statement focuses on an efficient IT and telecommunications infrastructure and on effective IT usage. What the steam engine and electricity were to the industrial society, IT and modern communications technology are to the knowledge society. IT and telecommunications increase the speed of knowledge dissemination while improving its accessibility.

Danish human capital - our human resources - is essential to the knowledge society. In this context, primary and lower-secondary schools, vocational education programmes, post compulsory schools, higher education programmes and continuing and further education programmes play a central role as intermediaries between knowledge suppliers and knowledge recipients. Which is why the Government's action plan, "Better Education," focuses on proficiency and quality, coherence in the educational system, the interaction between users, recruiters and stakeholders and life-long learning.

In this context, it is vital that knowledge institutions also exist which communicate and develop application-oriented knowledge. Thus, the purpose of the establishment of Centres for Higher Education and Vocational Academies has been to develop knowledge centres to ensure efficient dissemination of knowledge by way of agreements regarding research affiliation.

The Government's efforts in this area should also be seen in extension of the Government's growth strategy, "Determined Growth," which broadly targets business and industry's growth conditions, and the "National Action Plan for Employment," which is to improve and create a more coherent employment policy.

1.4 The allocation of funds for further investments and new reforms

The Government has allocated funds for further public-sector investments in knowledge. In connection with the 2003 Budget, slightly less than DKK 3.5 billion in supplementary appropriations has been earmarked for university programmes, research, IT and innovation for the financial period 2003-2005.

The allocation of funds for further investments in knowledge

- Last autumn's political agreement on universities involves almost DKK 1 billion of new appropriations for Danish universities over the next three years.
- The political agreement on research reserve capital ensures a total of DKK 700 million over the next three years for research and universities.
- The Government has set aside a reserve of DKK 0.5 billion for research and innovation.
- The Universal Mobile Telecommunication System (UMTS) agreement contributes DKK 1.2 billion to research and development over the next three years.

In addition to this, the agreement on "Better Education"entails the appropriation of DKK 477 million for education in 2003, where DKK 240 million are to go to a multi-year agreement for vocational schools and DKK 237 million to a one-year agreement for the rest of the education sector. In the 2003 Budget, a total of DKK 3.7 billion are earmarked for the implementation of "Better Education" for 2003-2005. Of these, approximately DKK 0.8 billion are not yet implemented.

Public-sector investments in the knowledge system could be gradually increased, however, not much will be achieved if private companies do not see a perspective in increasing their efforts in areas such as research and development. It is businesses who ultimately create financial growth. And one of the prerequisites to converting public investments into financial growth is that companies have the means necessary on the receiving end in the form of own knowledge bases, e.g. own research and development and highly educated employees.

The role of the public sector is to provide most of the knowledge, basic research and highly qualified workforce - all of which involves some sort of risk - by way of flexibility and coherence in the educational system, while, at the same time, strengthening an efficient IT and telecommunications infrastructure primarily based on healthy competition.

This focus on the need to invest in the Danish knowledge system should be followed by an effort to ensure that the public knowledge institutions are coherent, efficient and able to meet society's demands for greater openness and more interaction.

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Also in this area, the Government has taken the first step and prepared a number of comprehensive reforms in the university and research sector, which will be realised in the beginning of 2003 through draft legislation on universities, research counselling and the Danish National Research Foundation.

The combination of reforms and appropriations for investment in knowledge should ensure a considerable boost to the total knowledge effort. This strategy should also be pursued in coming years.

Another reform in the educational system

The political agreement on primary and lower-secondary schools means:

> Improved proficiency. Henceforth, centrally binding goals will be set for every subject taught at Danish primary and lower-secondary schools. Furthermore, pupils are to receive extra lessons in Danish, Mathematics, English, Physics/Chemistry and Physical Education.

> Children are to be better prepared for school. This will be achieved through, among other initiatives, the introduction of content descriptions which state the goals expected of nur-sery school classes.

> Better foundation for class formation and teaching differentiation.

> Investments in research, education, innovation and IT are essential growth factors in the global knowledge economy.

> Highly developed countries are experiencing increased competition in knowledge and technology. Access to highly educated knowledge workers attracts investments and workplaces.

> Knowledge production is becoming more global. The business and industry community plays an ever more important role as knowledge supplier and knowledge is an increasingly attractive commodity.

> Strong knowledge environments and participation in international networks is a necessary admission ticket to the global knowledge market.

2.1 Knowledge as an engine of growth

The world is changing. It is no longer safe and good to have acquired one's knowledge and competencies at one specific time in one's life, because competencies become rusty and outdated. Therefore, one must learn throughout life and keep abreast of new knowledge and new competencies. This development makes comparable demands to our workplaces and knowledge institutions for a new way of organising, which makes it possible to acquire knowledge throughout life.

This development also places new demands on how companies produce products and compete in the market. Whereas previously companies could come a long way by economising on resources and workers, today the ability to develop, acquire, communicate and utilise knowledge has become crucial for the creation of values.

And while a single sector - e.g. agriculture and industry - has previously been the driving force in the economy, we now see a new picture developing. Traditional distinctions are fading - between industry and service, between the public and the private sectors and between research and business. Knowledge and technology act as a locomotive, which spurs economic development - across different sectors. Knowledge is a key growth factor. This especially applies to countries like Denmark, with a high level of costs, which makes it difficult to compete with less expensive products from developing countries. In contrast, we must compete using products with a high knowledge content, high quality, good design and a good image.

In this way, the knowledge society brings with it a number of profound changes throughout the economy. The economy of the knowledge society is a distinctly global economy. Workplaces and investments are no longer protected by national boarder posts.

The transition from industrial society to service society was characterised by the movement of manual industrial labour to new low-pay countries. Now we are facing a new and different phase of the globalisation process. The removal of trade barriers and the spread of information and communication technology have led to a level of mobility in knowledge work and investments in innovation and high technology, never experienced before.

This is primarily due to large, global companies playing a still greater role in knowledge gathering and economic development on a global scale. These companies locate development activities and workplaces in countries that offer the best opportunities. In this context, access to highly educated experts and strong knowledge environments is often a decisive factor and, thus, a vital competitive parameter in national and regional races to attract new investments.

"The global knowledge economy" is a collective term for the phenomenon of knowledge as a driving force in the economy and of economic activity becoming less and less limited by national boarders. A number of scientific studies have attempted to capture the knowledge economy in figures, which is no easy task. However, these studies suggest that investing in knowledge is worthwhile.

Talented engineers behind mobile success in Northern Jutland

An open and powerful research environment at Aalborg University has made it possible for Northern Jutland to develop a significant industrial niche in wireless telephony. A well-developed regional labour market for highly qualified IT engineers has attracted for global companies like Siemens, LM Ericsson, Nokia and Maxon, all of which have opened branches in a region that previously was viewed as a fringe area.

Private companies invest in knowledge because it is the best way to increase their competitiveness and profitability. The public sector invests in knowledge because it strengthens the economy and benefits all of society.

The private sector invests less in knowledge with a return which lies far in the future and which, perhaps, benefit society in a broader sense. This applies, for example, to basic research, basic education and knowledge communication via e.g. the library system. The public sector can often benefit from

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investments in this type of knowledge because the socio-economic gains of investing in many cases are greater than the private economic gains.

Growth in the knowledge society - the expert assessment*

In the *research sector*, studies indicate that the private sector's investments in its own research and development generally involve a higher potential for growth than public sector research investments. However, for a country such as Denmark, without any significant driving forces in industry, studies also indicate that there is a need for a relatively larger percentage of public research investment. Investing in research is risky and the returns are often only apparent in the long term.

In the *education sector*, the OECD has estimated that an increase in the average educational level of one year would increase society's level of productivity by 5 to 10 per cent. Additionally, several studies indicate that the economic returns of public investment in research depend to a great extent on the education that is associated with the research. The education of Candidatus (Master) graduates and researchers, who ultimately find employment in the private sector, contributes much more than specific academic knowledge. For example, they can provide companies with the competencies to conduct their own research-based tasks and they also strengthen companies' ability to receiving knowledge. To ensure the effective dissemination of research results, it is vital that research and teaching are integrated activities.

Additional factors, which are important for societal returns from public investments in research and education are *innovative networks* and geographical proximity. Regional and professional networks are vital for the ability of companies to convert knowledge into innovation and growth. Foreign studies give examples in which up to 20 per cent of innovations in large innovative companies can be linked to publicly financed research. The studies show that the indirect effect of education, professional networks and the establishment of companies may be even higher.

Studies of the importance of *information technology* for economic growth suggest that IT plays an important role beyond growth in the IT sector itself. Thus, IT has substantially increased the productivity of society as a whole. The USA is farthest along - it is estimated that IT has contributed more than 20 per cent of growth in productivity in recent years. However, it takes time for investments in IT to be converted into increased productivity because profits also entail organisational changes as well as training of and new qualifications for employees. Because of such aspects, Europe still lags behind the USA with regard to outlining the economic benefits of IT.

* For a in-depth analysis of various studies regarding the correlation between knowledge and growth, please refer to Part 2, Chapter 2 of this report.

On the international political scene, this development has led to a new strategic focus on knowledge investment among the strong economies in Europe, North America and the Far East. The EU Commission has indicated that Europe's technological competitiveness is falling more and more behind that of the USA and Japan, especially due to a considerable backlog in investment in research and development. Therefore, at the Lisbon Summit in spring 2000, the EU countries initiated a joint process with a view to improving competitiveness, growth and employment via a more knowledge-based economy. The vision is for the EU to be the most competitive economy in the world by 2010.

2.2 New patterns in the production and dissemination of knowledge

Universities and other public knowledge institutions make up an important part of the knowledge society's foundation. They are responsible for most of the basic research conducted and for the education of new knowledge workers for the public and private sectors.

However, in certain areas, public research does not uphold a definitive dominance. More and more companies have specialised research and development departments of their own. This applies, for example, to biotechnology, where private research companies are seeking new fundamental understanding of diseases and the function of the human body in the search for new treatment methods and medications.

The new patterns in society's knowledge production have also challenged customary perceptions of how values are created and converted. The results of a single development project can send share prices on a serious roller coaster ride. The value of leading companies is increasingly based on their human resources and intellectual property rights - e.g. patents. Therefore, it is vital for innovative companies to be able to protect their investments in new knowledge through patents, among other things.

Knowledge as a commodity has become an important socio-economic factor, and highly educated employees are increasingly in demand. Companies mutually compete for particularly valuable expertise by means of pay, co-influence, employee shares and an attractive social and professional environment. Suppliers and customers increasingly act as learning partners rather than just trading partners. Therefore, it is more important than ever for companies in the knowledge society to stand out as competent and responsible partners with regard to employees, customers, suppliers and knowledge institutions.

The knowledge economy also entails considerable changes in public research. Knowledge institutions occupy a new strategic role in the development of society. It places demands on science for openness, for increasing social commitment and for contributing to the public debate.

Traditionally, public research has performed like a relatively closed exchange economy. New research results are made public, but generally only in scientific journals and at scientific conferences with a relatively limited recipient group. However, this reality is also undergoing a transformation now.

2.3 The global knowledge market

Both knowledge institutions and companies are increasingly taking part in a global knowledge market.

It is becoming more and more important for knowledge institutions to enter into networks with other leading public and private knowledge environments - without consideration of borders and languages. Quality is the crucial factor.

Telecommunications research in new hands
New IT knowledge is created and traded in new ways. The privatisation of the telecommunications market, both in Denmark and abroad, has resulted in national monopolies having to adapt, from being technology-oriented to becoming more customer-oriented. Several R&D departments of telecommunications companies, which previously were national technology locomotives, have been reduced or phased out, and their tasks have entirely or partially been outsourced to public knowledge institutions for a fee. At the same time, this has placed new demands on public IT research with regard to greater insight into the knowledge needs of the market.

Access to new advances as a result of international research is becoming ever more vital for business and industry. This includes the ability to require patent rights from public institutions at market value.

Furthermore, knowledge as a commodity can be embedded in new products and processes. This knowledge spreads primarily by way of commerce. However, the global knowledge market is not a traditional market in the sense that all new knowledge can be purchased as a matter of course.

Knowledge is often upheld by people - either as formal knowledge, which in principle also can be found in textbooks and articles, or as so-called "tacit knowledge", which is based on experience of how a particular task can best be handled in practice. While the more formal knowledge is easier to put a price on and to deal in, tacit knowledge is more difficult to assess.

Formal or tacit knowledge - in either case, the recipient needs to have the competencies to decode and utilise the knowledge. Moreover, a common professional and cultural understanding is often required between the sender and the recipient. Consequently, networks among knowledge producers and between knowledge producers and knowledge users are vital for maximising the potential of new knowledge.

International network in the fight against sclerosis
By virtue of his excellent research, Lars Fugger, professor and doctor at Aarhus University Hospital, has become the head of an international network of leading sclerosis researchers in Denmark, the UK, Sweden and USA. Thanks to this international collaboration, valuable knowledge on immunology and sclerosis has built up in Denmark, which could, in future, contribute to the development of new effective medication.

But networks do not establish themselves. Knowledge attracts knowledge. It is necessary to possess knowledge in order to access knowledge. Also in this context, one must have something to offer in order to be an attractive partner in the knowledge market.

This applies to knowledge institutions and companies - and it applies to regions and nations. Therefore, a national knowledge strategy cannot solely be based on importing and copying knowledge and technology from other countries. We must produce our own original knowledge and build up strong knowledge environments with international networks in order to succeed in the global knowledge market.

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- Few large - many small and medium-sized knowledge institutions. The activities in the Danish knowledge system are spread among a relatively large number of knowledge institutions. Compared to international standards, most of the Danish knowledge institutions are small. Within their respective areas a handful of large universities, government research institutes, hospitals and GTS institutes account for most of the public research, development and technological service conducted in Denmark.

- Danish companies have primarily focused on development work. The Danish business and industry community conducts about two-thirds of the total research and development carried out in Denmark. Companies primarily focus on development work that has an immediate commercial objective and to a lesser extent on basic and applied research.

- The knowledge-intensive industries make up only a fraction of Danish business and industry. In Denmark, the high-technology industries, e.g. the pharmaceutical industry and the IT and electronics industry, are responsible for a relatively modest percentage of the Danish business and industry community's total turnover and employment.

- Danish business and industry has a highly concentrated knowledge production. Approximately half of the Danish business and industry community's total investments in research and development in 1999 were made by the 50 companies, which invested the most in research and development. In the private sector, two-thirds of all employees with a university degree (master degree or PhD) higher education or a PhD are employed by fewer than 2,000 companies or 3 per cent of all Danish companies with five or more employees.

- There is a relatively moderate level of interaction with regard to research and development between companies and knowledge institutions. Half of the companies that conduct research and development collaborate with other private companies on research and development, while approximately one-fourth collaborates with public research institutions.

- The number of knowledge-based entrepreneurs is rising; the number of entrepreneurs in general is rising. At the same time, the number of start-up companies in the knowledge service and high technology industries has increased from 22 to 30 per cent.

- Only a few knowledge-intensive sectors provide knowledge to Danish business and industry. Much of the knowledge in Denmark is provided by a handful of knowledge-intensive sectors that function as suppliers of knowledge to large parts of the business and industry community. In this way, the majority of Danish companies, which are not particularly knowledge-intensive, can profit from the knowledge that stems from these sectors.

3.1 The Danish knowledge system

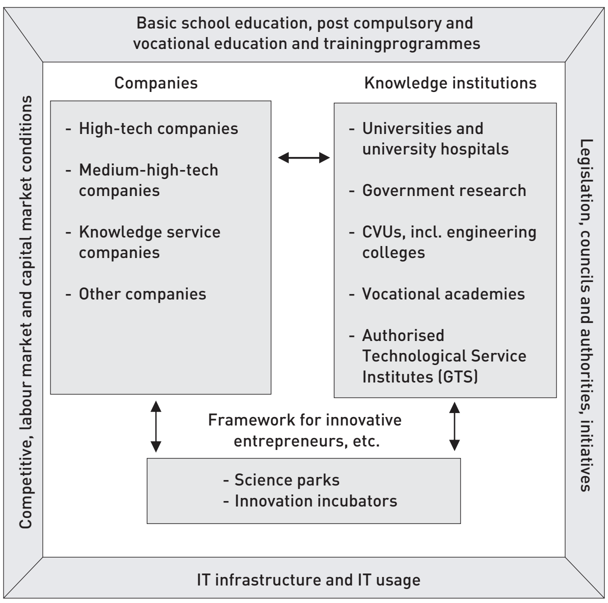
The Danish knowledge system is comprised of the knowledge institutions and private companies which produce, attract, disseminate and apply research-based or other advanced knowledge in Denmark and their related framework conditions and collaborations.

In this context, knowledge institutions include universities, government research institutes, university hospitals, Authorised Technological Service Institutes (GTS-institutes), Centres for Higher Education (CVUs) and vocational academies. In addition, there are science parks and innovation incubators which assist entrepreneurs and others with the commercialisation of research results. On the corporate side, the knowledge system primarily consists of that part of the Danish business and industry community which produces, attracts, disseminates and applies research-based and other advanced knowledge.

In addition to knowledge institutions and knowledge-based companies, the Danish knowledge system is dependent on a number of framework conditions, which contribute in various ways to setting the framework for how knowledge is produced, attracted, disseminated and applied in Denmark.

The Government's goal is for the Danish knowledge system to strengthen its position as one of the world's most efficient and competitive systems.

Figure 1: The Danish knowledge system – key players and selected framework conditions



3.2 Players in the Danish knowledge system

The Danish knowledge institutions

The Danish knowledge institutions are substantial knowledge producers in the Danish knowledge system.

In 2000, public research and development was conducted for approximately DKK 10 billion distributed as follows: almost DKK 6 billion were appropriated to universities, DKK 2 billion to government research institutes and DKK 1.5 billion to hospital and health services as well as almost DKK 0.5 billion to several other knowledge institutions, such as museums and libraries. In 2000, DKK 3.1 billion were appropriated to university education programmes.

In addition to this, there are appropriations to CVUs and vocational academies respectively, in order to: provide regional knowledge centre functions; support these institutions' commitments to privately and publicly co-funded development work; promote practice-oriented applied research and conduct entirely privately-funded development work.

Universities, Centres for Higher Education and vocational academies

Denmark's 11 universities[1] have three main tasks: To conduct research at the highest international level. To provide research-based Bachelor, Candidatus (Master) and PhD education programmes as well as research-based continuing and further education programmes. Finally, they must communicate knowledge to society through collaboration.

The Danish universities vary greatly in size, and they have very different academic profiles. Thus, in Denmark we have five universities with several faculties, which conduct research and provide Bachelor, Candidatus (Master) and PhD education programmes in natural sciences, humanities and social sciences, and other subjects. These universities are: the University of Copenhagen, the University of Aarhus, Aalborg University, the University of Southern Denmark and the University of Roskilde.

In addition, we have four single-faculty universities, which conduct research and provide education programmes aimed towards a small, well-defined number of professions. These are the Royal Veterinary and Agricultural University, the Danish University of Pharmaceutical Sciences, the Danish University of Education and the Technical University of Denmark.

Table 1: Key figures for university education results and resource consumption in 2001*

University	Students	Student man years**	Total exp. DKKm 2001 prices	AP person-nel***
University of Copenhagen	33,801	16,371	3,362	2,483
University of Aarhus	21,588	11,356	2,026	1,776
University of Southern Denmark	11,991	6,202	1,236	1,073
Aalborg University	10,834	6,859	1,169	1,095
Copenhagen Business School	9,962	6,221	623	622
University of Roskilde	6,698	3,878	180	515
Technical University of Denmark	5,472	3,853	1,549	1,318
Aarhus Business School	4,652	2,529	268	299
Royal Veterinary and Agricultural University	3,114	1,873	962	715
Danish University of Pharmaceutical Sciences	1,102	827	214	202
IT University of Copenhagen	686	392	84	53
Total	109,900	60,361	11,672	10,150

* Excluding the Danish University of Education. Source: University financial statements 2001.

** One student man-year means that exams have been completed equalling one-year's full-time study.

*** AP personnel includes permanently employed and part-time employed academic personnel calculated according to number of full-time employees.

At the universities, there is also technical and administrative personnel.

Finally, the two business schools in Aarhus and Copenhagen respectively, focus on research and education in the fields of business language and economics and business administration.

There are major differences in the size of the universities measured in terms of the number of students, number of graduates and ratio of number of students to academic personnel. Almost one-third of all students in Denmark are matriculated at the University of Copenhagen. Along with the University of Aarhus, these two Danish universities account for approximately half the enrolled students in the university sector. At the same time, together they incur almost half the costs in the university sector.

Since 1 July 2001, 23 Centres for Higher Education (CVUs) have been established. These centres provide Profession Bachelor programmes in the technical, commercial, IT, educational theory, social science and health science fields. CVUs act as regional, application-oriented knowledge centres supported by research affiliation agreements with universities. They deal with development tasks in relation to both private and public customers and help to ensure a close, flexible regional coherence between basic, continuing and further education in order to strengthen regional competency development. Especially CVUs in engineering, have contributed greatly to the establishment of innovation and entrepreneur incubators.

The vocational academies are regional collaborative initiatives among vocational schools responsible for technical, commercial and IT short-cycle higher education programmes and continuing higher education programmes for the adult population. 16 regional vocational academies have been established to fulfil knowledge and development functions in relation to the local and regional business and industry community. The technical, commercial and IT CVUs and vocational academies are usually geared towards and collaborate with a broader portion of the business and industry sector, including medium-high technology companies.

Government research

Denmark has 22 government research institutes which are covered by the Act on Government Research. The institutes vary greatly and fulfil very different functions. Organisationally, the institutes are currently attached to nine different ministries.

Government research primarily provides research-based knowledge which can form the foundation for the decisions made by politicians and regional and local authorities. In addition, these institutes perform a number of statistical, monitoring, counselling and public authority services in areas important to society. They also collaborate with universities to educate researchers. Government research represents approximately 20 per cent of the total public research.

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Table 2: Government research institutes, personnel and expenditure in 2001 (DKK million)		
Institution	R&D man-years	R&D expenditure
Danish Institute of Agricultural Sciences*	704	509
Risø National Laboratory	631	493
National Environmental Research Institute of Denmark	133	162
Statens Serum Institut (Danish National Serum Institute)	200	112
Danish Veterinary Institute**	137	107
Geological Survey of Denmark and Greenland (GEUS)	152	101
Danish Institute for Fisheries Research	117	90
Danish Veterinary and Food Administration	90	84
Danish Building and Urban Research	93	62
National Institute of Occupational Health	106	60
Danish Defence Research Establishment	22	52
Danish Space Research Institute	50	50
Danish Forest and Landscape Research Institute	92	44
Danish National Institute of Social Research	78	39
National Institute of Public Health	36	35
Danish Pest Information Laboratory	19	30
National Survey and Cadastre	33	26
Danish Research Institut of Food Economics	32	23
Danish Transport Research Institute	23	12
Centre for Language Technology	21	12
John F. Kennedy Institute	15	7
The Danish Institute for Studies in Research and Research Policy	14	6

Source: Danish Government Research Institutes Steering Committee – Danske sektorforskningsinstitutioner (Danish government research institutes) 2001/2002.

* R&D man-years for the Danish Institute of Agricultural Sciences (DJF) are 2000 figures; R&D expenditure for DJF are estimations based on 2000 figures.

** Danish Veterinary Institute is based on figures from the Danish Veterinary Institute for Virus Research and the Danish Veterinary Laboratory, which merged in 2002.

Hospital and health services sector

After universities and government research, the hospital and health services sector is the third largest player in public research. The hospital and health services sector is responsible for approximately 15 per cent of the total public research measured in terms of expenditure. This corresponds to approximately DKK 1.5 billion a year. By far the majority of this research is conducted under the auspices of the three university hospitals, under which 18 hospitals collaborate regionally with the health sciences faculties at the Universities of Copenhagen, Aarhus and Southern Denmark, respectively.

The university hospitals primarily conduct medical and health research, focusing mainly on experimental and clinical research in treatment methods, prevention and health promotion, neurology/psychiatry, genetics and biotechnology.

Table 3: University hospitals, personnel and expenditure in 2000 (DKK million)		
COPENHAGEN UNIVERSITY HOSPITAL:	R&D man-years	R&D expenditure
Copenhagen University Hospital - Rigshospitalet	478	339
Copenhagen University Hospital - Hvidovre	150	76
Copenhagen University Hospital - Bispebjerg	121	49
K.A.S. Glostrup Hospital	116	51
K.A.S. Herlev Hospital	111	55
K.A.S. Gentofte Hospital	42	23
Copenhagen University Hospital - Frederiksberg	28	13
Copenhagen University Hospital – St. Hans Hospital	13	7
Copenhagen University Hospital - Amager*		
Research Centre for Preventative Medicine*		
AARHUS UNIVERSITY HOSPITAL:		
Aarhus University Hospital	224	115
Aarhus University Hospital – Skejby	164	78
Aarhus University Hospital – Aarhus County Hospital	94	45
Aarhus University Hospital – Aarhus Psychiatric Hospital	69	34
Aalborg County Hospital	42	21
Aarhus University Hospital – Children's Psychiatric Hospital*		
ODENSE UNIVERSITY HOSPITAL:		
Odense University Hospital	184	119
Odense University Hospital – Middelfart		

Source: Research and development work in the health sector, Forskningsstatistik (Research statistics) 2000, the Danish Institute for Studies in Research and Research Policy, 2002.

* Data not available for this unit.

Furthermore, research is conducted at a number of individual clinics and centres, at the Danish Cancer Society and, to a lesser extent, at several other public hospitals outside the large university towns.

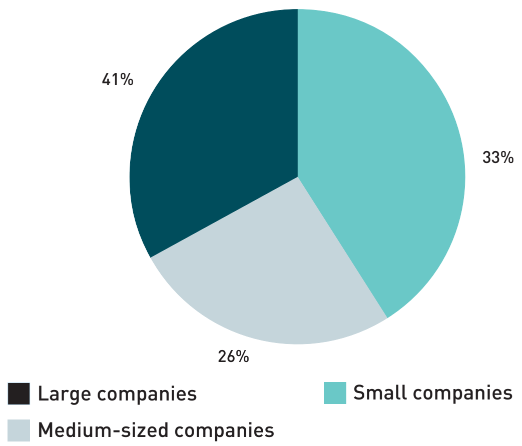
Authorised Technological Service Institutes

The Authorised Technological Service Institutes (GTS-institutes) are private, self-governing institutions which provide knowledge and competencies to Danish business and industry for a fee. The GTS institutes play a vital role as producers and communicators of application-oriented and technological knowledge, especially for small and medium-sized enterprises.

On an annual basis, the ten GTS institutes sell services to approximately 18,000 different Danish companies. These services span from testing, verification and certification to advanced technological counselling, research and development.

The GTS institutes generated a turnover of more than DKK 2.2 billion in 2001. Of this, approximately DKK 1 billion was in sales to Danish companies. Sales to large companies with more than 200 employees make up more than 40 per cent of the turnover. The remainder comes from small and medium-sized companies, which make up more than 90 per cent of the institutes' total number of customers. The two largest GTS institutes, the Danish Technological Institute and FORCE Technology, are responsible for more than half the employees, total turnover and public co-financing.

Figure 2: Domestic commercial turnover by company size, 2001



Source: Performance reports from GTS Institutes, 2002.

On the basis of results contracts between the GTS institutes and the Council for Technology and Innovation, the GTS institutes receive public co-financing to develop and maintain their technological knowledge and competencies.

Over the last decade, the institutes have undergone a major change. From being predominantly publicly financed research and testing institutions, they are now market-driven knowledge service companies with relatively limited public co-financing. Today, public co-financing makes up more than DKK 240 million per year, which corresponds to approximately 11 per cent of the institutes' total turnover.

Table 4: Authorised Technological Service Institutes in Denmark (GTS institutes)

Institute	Turnover 2001 (DKK million)	Employees in 2001	Public financing 2001 (DKK million)
Danish Technological Institute	678	931	95.1
FORCE Technology (incl. Danish Maritime Institute)	574	818	35.7
DHI – Water and Environment	301	363	28.9
DELTA – Danish Electronics, Light & Acoustics	233	249	24.3
Danish Standards Association	133	173	17.6
dk-TEKNIK ENERGY & ENVIRONMENT 111	156	6.0	
Biotechnological Institute	83	144	15.0
Danish Institute of Fire and Security Technology	58	93	6.3
Danish Toxicology Centre	29	44	4.3
DFM – Danish Institute of Fundamental Metrology	17	24	9.3
Total	2,233	2,977	242.5

Source: Reports from the GTS Institutes.

The framework for innovative entrepreneurs, etc.

Denmark's seven science parks and eight innovation incubators also form part of our knowledge system.

Table 5: Innovation incubators

	Innovation incubalator No. of new trail projects 1998-2001	Allocation of capital to start-up companies 1998-2001 (DKK million)	Allocation of private capital in addition to public capital 1998-mid2002 (DKK million)
Technology Innovation	110	72	175.0
CAT – Symbion Innovation	61	39	278.0
NOVI Innovation	57	36	25.0
DTU Innovation	54	38	71.0
Østjysk Innovation	52	41	57.9
HIH Development	39	22	46.0
Syddansk Innovation	36	30	22.5
BioVision (began 2001)	11	8	0.6
Total	420	286	676.0

Source: Reports from the institutes.

The science parks are: Symbion Science Park, CAT Science, Danish Science Park at Hørsholm, International Science Park Odense, NOVI A/S, Agro Business Park and Science Park Aarhus. They mainly provide space, administrative services and laboratory facilities. In addition to entrepreneurs, they also house other types of innovative companies.

The science parks are organised as independent private companies, but receive various types of funding from central, county and local authorities, e.g. through access to site areas on favourable terms.

Two new science parks

Two new Danish science parks for IT and biotechnology are being established. Here entrepreneurs, innovative companies, development projects from existing businesses, students and researchers will have the opportunity to inspire each other across institutional and sectorial boundaries and, thereby, develop new creative and high-technology companies.

The IT science park is to be established in conjunction with the IT University of Copenhagen in Ørestaden and in close affiliation with the Danish Broadcasting Corporation's new multi media building and the University of Copenhagen's Faculty of Humanities on Amager. The biotechnology science park is to be established in the future BioCenter at Tagensvej in Copenhagen in close affiliation with the Panum Institute, the Biotech Research and Innovation Centre (BRIC) and Copenhagen University Hospital.

The purpose of innovation incubators is to contribute to the commercial utilisation of new ideas and research results. Innovation incubators usually provide support to entrepreneurs at a very early stage, when private investors are reluctant to invest due to uncertainty regarding the company's future returns.

Innovation incubators possess the competencies to evaluate whether projects have commercial potential. If the preliminary study shows that there is a sound basis for establishing a company, the innovation incubator can co-finance the project on the State's behalf. Furthermore, innovation incubators continually assist the start-up companies with professional and managerial competencies.

Innovation incubators are private companies, which have been approved by the Ministry of Science, Technology and Innovation on the basis of public tenders. In the 2003 Budget, approximately DKK 130 million is earmarked for innovation incubators.

Since 1998, innovation incubators have contributed to the establishment of 420 start-up companies. They have invested almost DKK 300 million and attracted approximately DKK 680 million in supplementary capital.

The majority of Danish science parks and innovation incubators take part in joint groups as independent companies. This means that science parks and innovation incubators are usually clustered together and are often affiliated with a public knowledge institution.

Companies in the knowledge system

Companies are the heart of the Danish knowledge system. The business and industry community is a major producer of knowledge, and it is almost exclusively companies, which convert knowledge into new technology and innovation. Therefore, companies play a central role when it comes to putting knowledge to use and to converting knowledge into financial growth.

Danish companies have primarily focused on development work

Over a ten-year period, the Danish business and industry community has steadily increased its expenditure on research and development. However, Denmark continues to lag behind other leading countries in this field when considering the business and industry community's R&D expenditure compared to gross domestic product (GDP). Danish business and industry invests the equivalent of 1.7 per cent of GDP in research and development while business and industry in so-called leading knowledge economies invest between 2 and 3 per cent.

In 2001, Danish companies spent approximately DKK 22 billion on research and development (R&D). This corresponds to more than two-thirds of the total expenditure on R&D in Denmark. These companies primarily focus on development work which has an immediate commercial objective and to a lesser extent on basic and applied research. Thus, 80 per cent of the man-years spent on research and development in Danish business and industry in 1999 has been devoted to development work.

The knowledge-intensive industries make up only a fraction of Danish business and industry

The knowledge-intensive industries make up only a fraction of Danish business and industry. Thus, companies in the high technology industries (such as the pharmaceutical and IT and telecommunications industries), the medium-high technology industries (such as the chemical and machine and electronics industries) and knowledge service industries (such as counselling, analysis and marketing companies) together represent almost 16 per cent of the Danish business and industry community's total turnover and employ more than 18 per cent of all employees in that community, cf. Table 6.

Table 6: The structure of Danish business and industry

	No. of companies 1999	No. of employees 1999	Percentage with long-cycle higher education	Percentage of turnover 2001	R&D expenditure as percentage of sector's value creation
High-tech industries	1,400	2.5 pct.	11 pct.	6.1 pct.	18.5 pct.
Medium-high-tech industries	4,800	6.4 pct.	4 pct.	3.4 pct.	6.4 pct.
Knowledge service	42,200	9.3 pct.	24 pct.	6.4 pct.	1.4 pct.
Other	187,800	81.8 pct.	3 pct.	84.1 pct.	0.7 pct.
Total private sector	236,200	100 pct.	6 pct.	100 pct.	2.6 pct.

Source: Statistics Denmark, 2001.

The research and development effort is highly concentrated in Danish companies

Approximately half (45.5 per cent) of the Danish business and industry community's total investments in research and development in 1999 were made by the 50 companies which invested the most in research and development. These are mainly companies in the IT, pharmaceutical, knowledge service and engineering (machinery!) sectors.

This is also apparent in the fact that two-thirds of all employees with a university degree (master degree or PhD) higher education or a PhD are employed by fewer than 2,000 Danish companies. This corresponds to 3 per cent of the Danish companies with five or more employees. These relatively few companies employ two-thirds of all knowledge workers in Danish business and industry.[4]

Companies' needs for knowledge vary greatly

Companies have different needs when it comes to access to knowledge. For instance, companies in the high technology and knowledge service sectors to a great extent base their knowledge on knowledge from universities, e.g. through their employees.

Many of these companies often need direct access to the results of basic research and need close collaboration with knowledge institutions on e.g. continuing education and technology development.

The medium-high technology companies in Denmark often base their product development on application and development-oriented research.

They usually need to supplement their core competencies with knowledge of new practice-oriented technology and research and, thus, they need close contact with e.g. technological services. Companies are often sub-contractors and collaborate in production networks with other companies. Contact with other public knowledge institutions, such as universities and government research, Centres for Higher Education, institutions for business and industry-aimed education, including vocational academies, is becoming increasingly important for this type of companies.

Among the remaining companies, there are many which do not have any significant contact with research institutions. A large portion of these companies quite simply does not need this contact. However, some of the more innovative companies in this group have difficulties applying research results from universities and government research. Usually, such companies do not have employees with research or development competencies, such as technicians, engineers or others with a university degree (master degree or PhD) education, to convert knowledge obtained from research institutions into actual innovation. However, a portion of these will often be in contact with regional educational institutions.

In spite of the fact that a large portion of these companies do well, it is nevertheless a great challenge to get a larger portion of them to enter into closer relationships with the rest of the knowledge system. The transition to knowledge-based production does not only involve those companies which already base their production on knowledge. To a great extend it involves the majority of the entire business and industry community.

The number of entrepreneurs within the knowledge service and high-technology industries in Denmark is rising

Entrepreneurs within the knowledge service and high-technology sectors play a vital role in the knowledge system. They often develop and commercialise new technologies and services. Furthermore, they often deal with the more risky and pioneering innovations, which, in return, also possess greater growth potential.

From 1995 to 2000, the number of newly established companies in Denmark increased from approximately 14,000 to just under 19,000 a year. At the same time, entrepreneurs in the knowledge service and high technology sectors represent an increasing portion of the new companies. For instance, in 2000 they amounted to 30 per cent of the start-up companies in Denmark compared to 22 per cent in 1995. Generally, entrepreneurs in the knowledge service and high technology sectors do slightly better than companies in the other industries. They stay afloat slightly longer and the high technology industries, in particular, experience higher than average growth in turnover.

3.3 The flow of knowledge in the Danish knowledge system

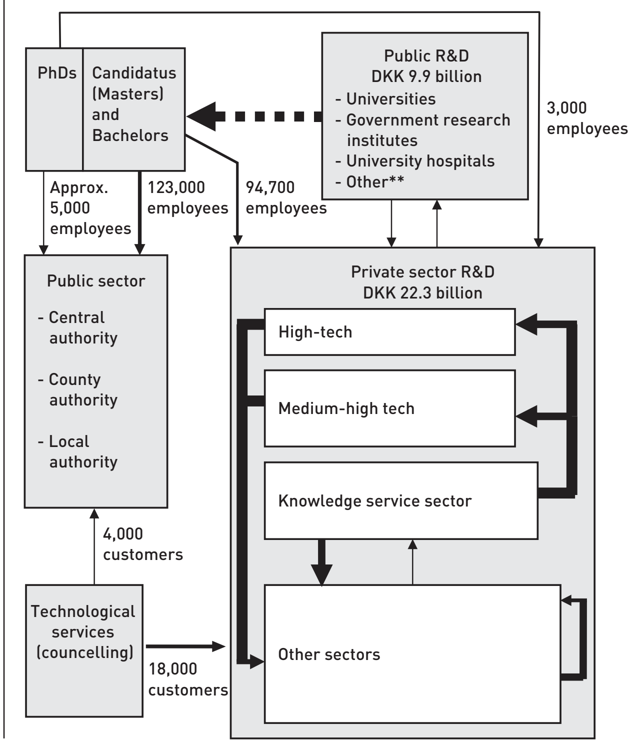
The knowledge system's various elements are closely connected. Knowledge produced in one area of society is often applied in several other areas. For this reason, a healthy interplay between the players in the knowledge system is important for the efficiency of the knowledge system as a whole in that it makes it possible to produce, disseminate and utilise knowledge effectively.

The flow of knowledge in the Danish knowledge system is very complex and difficult to describe through data. Figure 3 shows in general terms who produces knowledge in Denmark and how this knowledge moves about in society.

Public research also contributes to the knowledge development of the rest of society. This primarily takes place via research-based teaching at universities. The universities' education of Candidatus (Master) and PhD graduates is one of the most important sources of dissemination and transfer of the universities' knowledge. PhDs and other university graduates are employed fairly equally in the public and private sector.

Employees with a university education are predominately employed in knowledge services. However, there are also many workers with a university degree (master degree or PhD) at the often-large high technology manufacturing companies. Especially high technologies, and pharmaceutical industries in particular, employ a relatively large number of PhDs.

Figure 3: Flow of knowledge in Denmark 2000, 2001*



Source: Statistics Denmark 2000. Uddannelsesstatistikken (Education statistics) 2001.Forskningsstatistikken (Research statistics) 2001.

* There are a total of 9,200 PhDs in Denmark. At the present time, the so-called PhDregister and Statistics Denmark are not fully combined so the number of PhDs employedin the public sector may be imprecise.

** "Other knowledge institutions" covers museums, archives, Centres for HigherEducation, vocational academies, etc.

Another important source for knowledge dissemination is research affiliation agreements between universities and Centres for Higher Education. The purpose of these agreements is to ensure the communication of research results to the rest of the educational system. In this way, the universities can help to qualify the labour force in general and to underpin the application and practice-oriented development.

The GTS institutes contribute highly to the development and dissemination of technological knowledge. These institutes annually sell services to approximately 18,000 different private companies and 4,000 customers in the public sector.

IT and telecommunications also contribute substantially to the dissemination of knowledge in Denmark. In general IT usage in Denmark is high. For instance, IT workers are distributed in both the private and public sectors.

In addition to the actual IT sector, there are a large number of IT workers in the engineering industry, finance and insurance sectors, wholesale trade, research and development and utility sectors.

Generally, there is limited collaboration on research and innovation between the Danish public knowledge institutions and private companies. The public sector and the business and industry community only to a limited extent finance joint research and development projects. Overall in 1999, business and industry financed 3.5 per cent of the public sector's investments in research and development.

Companies also increasingly draw more on knowledge from other companies than from knowledge institutions. Half of all companies which conduct research and development do so in collaboration with other private companies. In this regard, Denmark ranks highly relative to other countries. But only 25 per cent of the companies, which conduct research and development, collaborated with public research institutions in 1999.

In the Danish business and industry community, research-based knowledge production is concentrated in relatively few sectors and companies. However, this knowledge does make use of a broader circle of companies in that knowledge from these companies is disseminated to the rest of the business and industry community through sales of goods and equipment. Knowledge transfer between the various sectors can, therefore, be analysed by studying the knowledge transferred with the goods and services which act as manufacturing input from one sector to another.[6]

Much of the knowledge in Denmark is developed in a handful of knowledge-intensive sectors that function as suppliers of knowledge to large parts of the business and industry community. Business services and machine manufacturing have a special status as the sectors, which supply the most knowledge. The reason for this is that these sectors act as sub-contractors of services and manufacturing equipment to large portions of the business and industry community. The highly knowledge-intensive telecommunications equipment and engineering sectors also supply a good deal of knowledge through the sale of equipment to other sectors.

With the exception of the pharmaceutical industry, which is a knowledge enclave with very little spill-over to other sectors, there is extensive commerce and exchange of knowledge between the other knowledge-intensive sectors and the business and industry community in general.

In this way, the majority of Danish companies, which are not particularly knowledge-intensive, can profit from knowledge coming out of sectors with high knowledge content. For instance, this applies to the large and financially important food industry, which is a large knowledge recipient.

In other words, knowledge gets around in many ways, and knowledge is often useful in other sectors than where it is produced.

The international flow of knowledge

Another type of knowledge flow is international in character. Knowledge systems become more and more interlinked across national boarders. This is also true of the Danish knowledge system, which increasingly exchanges knowledge with other countries.

It is an advantage for Denmark that we gather knowledge from abroad which we can utilise later. Therefore, it is highly preferable that we are able to attract knowledge workers and knowledge-intensive investments from abroad and enter into international collaborations. However, this does not mean that the knowledge which leaves Denmark is necessarily a loss. With regard to knowledge workers, many return to Denmark where they act as bridge builders to new knowledge from abroad. Generally, a strong international interplay forms the basis for good network connections with other countries, in this way creating access to a much larger knowledge base. International collaboration is the term for simultaneously obtaining and exporting knowledge to and from Denmark.

The foreign direct investments in R&D in Denmark were DKK 1.4 billion in 1999. Of this, approximately DKK 1 billion went to business and industry. This means that foreign players financed just over 6 per cent of the business and industry community's R&D. Similarly, foreign funding contributed DKK 0.4 billion to universities and other Danish research institutions.

Each year, Denmark receives approximately DKK 0.75 billion from EU research programmes. Denmark ranks fourth on the list of countries which receive the most EU funding for R&D compared to GDP.[7] Of these EU funds, 30 per cent go to the universities, 37 per cent to other research institutions and 27 per cent to companies.

Generally, Danish knowledge institutions and companies collaborate on R&D with other Danish players. Collaboration with foreign players is less significant and aimed at players in markets close to home, especially within the EU.

Of companies which collaborate with other players on R&D, 30 per cent indicate they only collaborate with companies or knowledge institutions in Denmark, 25 per cent collaborate mainly in Denmark and the EU and a further 25 per cent also collaborate with partners from the rest of the world.[8]

High technology products are a vital source for knowledge dissemination. The export of high technology products can also give an indication of the knowledge content in the products and of a country's innovation efforts. Denmark imports almost as many high technology products as we export. In 1999, Danish imports totalled DKK 60 billion and exports DKK 66 billion. High technology products make up approximately 20 per cent of Denmark's exports, which places Denmark in the middle segment in the OECD, slightly lower than several comparable countries. For instance, Ireland, the Netherlands, Great Britain and the USA have export shares of between 30-45 per cent.

Each year, approximately 3,500 Danes with a university degree (master degree or PhD) education emigrate to other countries. Approximately half have a technical/natural science education. This figure should be seen in light of the fact that there are approximately 150,000 Danes with a university degree (master degree or PhD) - of which approximately 30,000 have a technical/natural science education. A large portion is only out of the country for a short period. It is presumably fewer than 1,000 who emigrate for periods of more than five years.[9]

Generally, Denmark has few foreign knowledge workers. About 400 highly educated persons, especially with engineering and IT educations, receive work permits each year. To this should be added an equivalent number of immigrants with university degree (master degree or PhD) educations. It is not possible to draw any definitive conclusions, as the immigration/emigration figures cannot be compared.

PhDs in Denmark are becoming increasingly more international. The 449 foreign PhD students in Denmark (1999) correspond to 9 per cent of all research students. Furthermore, they help to bring knowledge of high quality into Denmark from sources abroad. Similarly, there were 247 Danish PhD students abroad.

With regard to students studying abroad, Denmark ranks slightly lower than the other countries with which we normally compare ourselves. In absolute figures, however, the number of Danish students who study abroad is increasing. In 2000, more than 4,300 students took part in exchange programmes and almost 4,400 followed an entire programme abroad funded by Danish study grants.

In general, this paints a picture of the Danish knowledge system as becoming more and more internationalised, which is a great advantage for our small knowledge base. However, this development brings with it a number of challenges, not least with regard to whether we can attract and maintain well-qualified knowledge workers, who form the foundation for the Danish knowledge environments.

3.4 Framework for the Danish knowledge system

The basic framework conditions are also of great importance for how the Danish knowledge system functions.

Basic, post-compulsory and vocational education

Good, relevant education programmes are an important prerequisite for a highly qualified work-force with up-to-date qualifications. Thus, the frame-work for basic, post-compulsory and vocational education and their coherence within the higher educational system is an important basic condition for knowledge in Denmark.

The foundation for knowledge is already laid in primary and lower-secondary school, and all studies emphasise the importance of primary and lower-secondary school for competency development. A pupil who enters school in the first form can expect to spend on average 15.1 years in the educational system. This represents a wide spread in which 5 per cent on one end of the scale only receive nine to ten years of education, while the 18 per cent on the opposite end who embark on a university education receive an average of 20 years of education. A post-compulsory education usually lasts three years, and the average length of study at university level is approximately six years for students who receive a Candidatus (Master) degree.

Relatively speaking, Denmark spends a relatively large amount of money on education compared to other countries, especially on primary and lower-secondary education. However, the share of the population with a university degree (master degree or PhD) higher education is lower in Denmark than in other countries. This is due to, among other things, the fact that there are excellent opportunities in Denmark to obtain vocational qualifications via a post-compulsory, short or medium-cycle higher education.

Legislation, councils and authorities and initiatives

The Danish knowledge system is also directly influenced by different legislation. The public knowledge institutions are often established in accordance with an act such as the University Act, the Act on Government Research Institutes, the Act on Technology and Innovation, the Act on Non-profit Institutions for Higher Education and the Act on Institutions for Business and Industry-aimed Education. These acts describe the general purpose and responsibilities of the institutions as well as dictate how they should fulfil their roles.

The production and protection of knowledge is also regulated by legislation, such as researcher patents laws (Act on Inventions at Public Research Institutions). The purpose of this Act is to promote patenting and commercialisation of research-based inventions. The Act establishes how rights and revenue from research patents are to be distributed and who may enter into agreements with private companies. Ethics are also governed by several acts, which set limits to what and how research may be conducted in specific areas. This is the case for such areas as genetic research and research involving experiments with animals.

However, the public sector also plays a role in other ways, such as in connection with the structure of political counselling and appropriations regarding research, education and innovation. This is the case for the research counselling system and the Council for Technology and Innovation, which together grant a large portion of the annual funding earmarked for research, innovation and education in supplement to the universities' basic grants.

Competitive, labour and capital market conditions

Moreover, market-oriented frameworks also play a major role, especially for companies' knowledge production and application as well as the recruitment of workers.

For instance, this applies to the conditions for competition. Effective competition is a prerequisite for the best possible utilisation of society's resources. At the same time, effective competition puts strong and healthy pressure on companies to renew and develop themselves. Thus, effective competition encourages companies to reduce costs and to develop new products which the market has not yet seen. Compared with a number of EU countries, Denmark currently ranks just under average with regard to effective competition, while in certain sectors, e.g. construction, competition is very poor.

Labour market conditions are also important. These conditions influence such aspects as the population's incentives to obtain an education and find work. They also influence companies' incentives to recruit new workers and ensure them continuing education and training. In general, the Danish labour market is healthy. Employment levels are high - especially due to the high numbers of women in the labour market. Unemployment is quite low, and mobility rates are high due to, among other things, the relatively liberal rules for appointments and dismissals. Nevertheless, Denmark has a high tax level, which may keep some from making an extra effort.

Furthermore, the conditions in the Danish capital market play a role in entrepreneurs' and companies' abilities to raise capital for new projects. There are many indications that the market for venture financing is growing in Denmark, however, it is still underdeveloped compared to the countries with which Denmark is normally compared.

The Danish competitive conditions, etc. are described in more detail in the Government's growth strategy, "The Danish Growth Strategy".

IT infrastructure and IT usage

Finally, IT and telecommunications constitute an important framework condition which relates to both the infrastructure and the general conditions for IT and telecommunications usage.

Advanced wireless telecommunications services generally ensure a more efficient communication, hereby contributing to improving the knowledge system. The more information and services one literally has at hand in the form of a mobile terminal, the more efficient one can be in planning working procedures and knowledge sharing.

Crossroads Copenhagen

Crossroads Copenhagen is a collaboration between private and public institutions. The participants are, among others: the IT University of Copenhagen, the Danish Broadcasting Corporation, the Royal Library, the University of Copenhagen Faculty of Humanities (KUA), Nokia, CSC, TDC, Hewlett-Packard, Skanska and Dagbladet Børsen (Danish financial daily). The purpose is to turn Ørestad North into an international development centre within culture, media and communications technology. Among other things, Ørestad North will be a testing ground in connection with the development of new, wireless services for mobile terminals such as mobile phones and PDAs (Personal Digital Assistants).

This also contributes to an increased degree of mobility. In Denmark, this process is underpinned by efficient frequency administration and the availability of new wireless technologies.

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However, the infrastructure consists of more than just cables and radio waves. For the infrastructure to function efficiently, common standards for the exchange of information are necessary.

The public sector in Denmark is a driving force in this process, among other things, due to its size. For instance, an information structure database has been established in the public sector. This is an Internet database which makes it possible to search for the information needed to make it easier to integrate different IT systems and to establish a common public infrastructure. This public effort is taking place in close collaboration with the market to ensure that the initiatives already initiated remain part of the infrastructure as a benefit to all of society as well as to the business and industry community.

Grid computing

IT and telecommunications are also important for research. One example is grid computing in which several super computers are connected in a network. Geographically the computers can be located far from each other, but when connected in a network they can perform calculations which would be unrealistic for a single computer.

Today, grid computing is used by seismologists to simulate the effects of earthquakes on cities. Geologists use it for 3-D simulations when drilling for oil. Biochemists use the technology to simulate the effect of infections on the human body. Cosmologists compute data from outer space and physicists use grid computing in particle physics. Even business and industry can benefit from grid computing, which opens many opportunities within, for instance the biotechnology industry.

[1] With the new University Act, which is expected to become effective mid-2003, the IT University of Copenhagen will become Denmark's 12th university.

[2] The number of companies is rounded off to the closest hundred.

[3] Value added is turnover less cost of goods sold.

[4] The Ministry of Science, Technology and Innovation in conjunction with Statistics Denmark has surveyed the number of companies in Denmark which have at least five employees with a university degree (master degree or PhD) higher education or a PhD. Furthermore, the employees with this level of education should constitute at least 10 per cent of all employees in the company.

[5] There are a total of 9,200 PhDs in Denmark. At the present time, the so-called PhD register and Statistics Denmark are not fully combined so the number of PhDs employed in the public sector may not be precise. The university educated in the figure includes both Candidatus (Master) and Bachelor graduates.

[6] The Industry and Trade Development Council: Den videnbaserede økonomi - en analyse af videnintensitet og vidensstrømme i det danske innovationssystem (The knowledge-based economy – an analysis of knowledge intensity and flow in the Danish innovation system). DISKO report no. 4, 1998.

[7] In relation to population size, Denmark ranks first; in relation to gross domestic product, Denmark ranks fourth.

[8] The Danish Institute for Studies in Research and Research Policy: Erhvervslivets forsknings- og udviklingsarbejde (Business and industry's research and development work), Forskningsstatistik (Research statistics), 1999.

[9] At this time, it is not statistically possible to document whether knowledge workers emigrate permanently or for a shorter period of time.

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- Danish research is in growth. The total public and private expenditure on research and development has been on the rise for the last ten years and has now reached a level of approximately 2.4 per cent of Denmark's GDP - or DKK 32 billion. Although this is above the EU average, it is lower than other leading research nations, which have achieved 3 per cent of their GDP. The private sector has been a driving force for the growth in Danish R&D expenditure in recent years.

- Public research provides quality for the money. When measured in terms of the number of international publications and cited articles, the quality is very high. This must be viewed in light of the fact that the level of investment for public research and development over several years has remained fairly constant and is in line with the EU average, but below the level of leading research nations such as Sweden and Finland.

- The level of education in Denmark has greatly improved over the last 20 years. Of the adult population, 27 per cent has completed a course of higher education, compared with the average for the OECD of 23 per cent. 18 per cent of a generation of young adults in Denmark begins a university education, which is slightly below the OECD average. Between 1990 and 2000, the number of PhDs has more than doubled from approximately 400 to 900 per year. In recent years, Danish universities have admitted approximately 1,100 new PhD students a year.

- Danish companies are innovative, but their interaction with knowledge institutions is relatively moderate. Approximately 40 per cent of Danish companies with more than ten employees have made innovations between 1998 and 2000. This means that they have either introduced a new or improved product to the market or that they have introduced considerably improved production processes within their company. Only a small number of companies' innovations are new to the market. Slightly more than every tenth of these innovative companies has directly involved a Danish university or other public research institution in their innovation efforts.

- IT usage is widespread in Denmark. Denmark has the highest Internet penetration levels in the EU. Of all Danish households, 65 per cent have access to the Internet compared to an EU average of 40 per cent. Compared to other countries, Denmark not only has a large number of Internet connections, the share of high-speed connections is also large and increasing rapidly.

4.1 Denmark is well equipped for the global knowledge economy

Denmark has a relatively sound basis for knowledge production and application. This is the general conclusion based on the comprehensive documentation of the Danish knowledge system, which forms the basis for the Government's knowledge strategy. Measured in terms of research, education, innovation and IT development, Denmark ranks quite high in most comparisons.

Generally, we do not yet utilise our investments in knowledge well enough to create value, new products and competitive advantages. On the other hand, the figures show that the business and industry sectors, which invest in knowledge, are also the sectors which generally create more value. For example, this applies to companies in the IT, telecommunications and pharmaceutical industries.

Companies in these sectors focus intensely on research, education, innovation and IT and they contribute quite a lot to Denmark's overall economical development, even though they are not very dominating in the business and industry community as a whole.

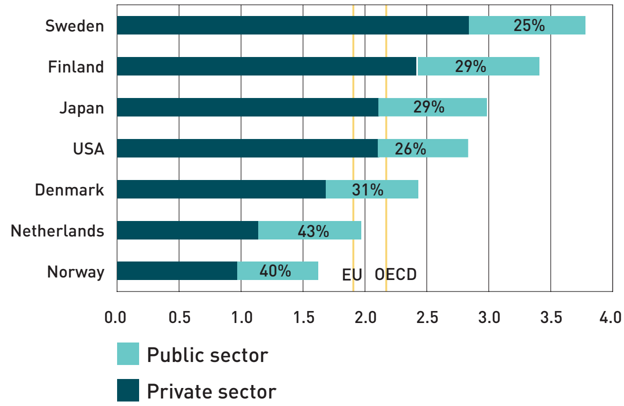
4.2 Research: High quality in public research

New knowledge may be the foundation for solving pollution problems, developing healthier foods or making manufacturing in the private sector more efficient. This is why good research is important for every knowledge society. Research can produce the new knowledge, which drives development forward.

For this reason, many countries have conducted more research in recent years.

In 2001, Denmark invested approximately 2.4 per cent of its gross domestic product (GDP) in research and development (R&D). Finland and Sweden, along with the USA and Japan, lead the way with investments of between 2.8 and 3.8 per cent of GDP. On average, EU countries invested approximately 2 per cent of GDP in R&D in 2001.

Figure 1: R&D as a percentage of GDP broken down by sector, 2001



Source: OECD - Main Science and Technology Indicators 2002:2.

Note: Exceptions to 2001 as reference year: EU, OECD, Netherlands and Japan: 2000; Sweden: 1999.

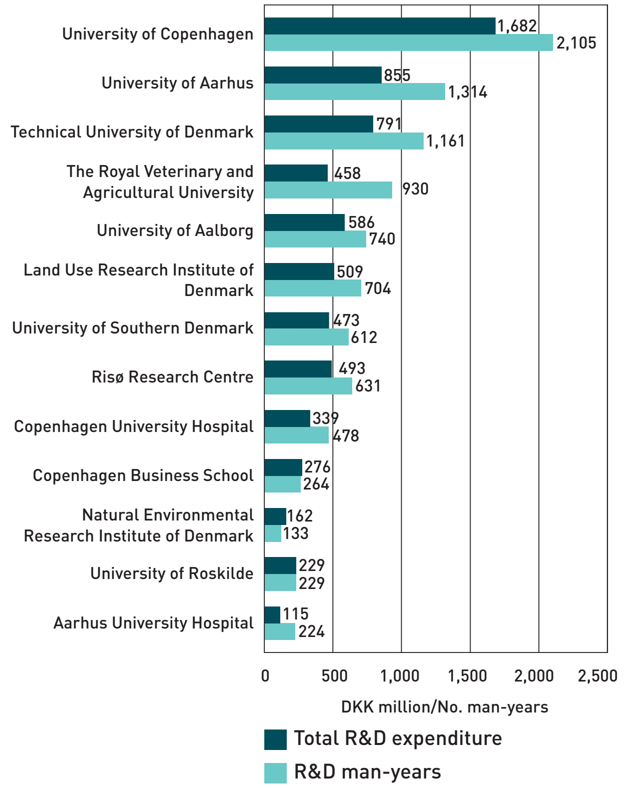
Public and private research should supplement each other in an efficient division of labour in order to utilise the resources for research optimally.

In Denmark, the public sector is responsible for nearly one-third of the total research, corresponding to around 0.7 per cent of GDP. The private sector, on the other hand, is responsible for more than two-thirds of the research, corresponding to approximately 1.7 per cent of GDP.

In 2001, the private sector had expenditures for research and development of more than DKK 22 billion.

The public knowledge institutions had expenditures for research and development in 2001 of approximately DKK 10 billion. By far the majority of the research took place either at universities, government research institutes or in hospitals and the health services sector. Consequently, these three areas together account for 96 per cent of the public research measured in relation to expenditure. Figure 2 shows an overview of the largest Danish public research institutions measured in terms of R&D expenditure and man-years.

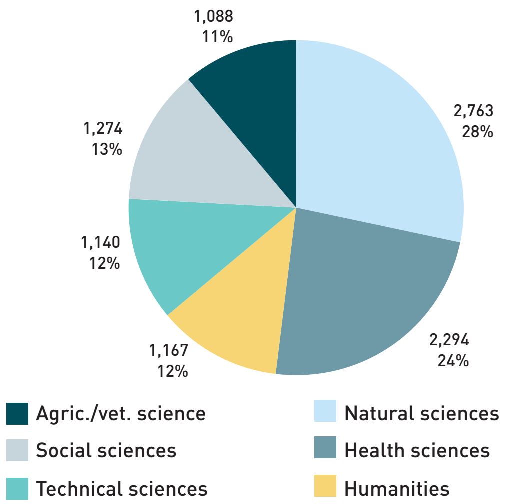
Figure 2: Denmark's largest public research institutions, 2001



Source: Offentlig forskningsstatistik (Public sector research statistics) 2000; Steering Committee of the Danish Government Research Institutes - Danske sektorforskningsinstitutioner (Danish Government Research Institutes) 2001/2002; the Danish Institute for Studies in Research and Research Policy - Forskning og udviklingsarbejde i sundhedssektoren - forskningsstatistik (Research and development work in the health care sector - research statistics) 2000.

More than half of the public research in Denmark takes place in the health and natural sciences sectors. The remaining effort is fairly equally distributed in the areas: technical sciences, humanities, social sciences and agricultural and veterinary sciences.

Figure 3: Public R&D investment by research field, 2000 (DKK million)

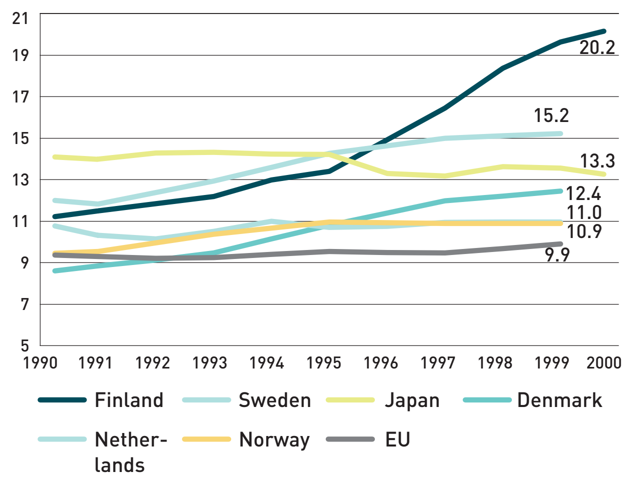


Source: Offentlig forskningsstatistik (Public sector research statistics) 2000.

Qualified researchers are an important building block when it comes to increasing research in a country. The Danish universities are, therefore, faced with a very important task: to educate future generations of researchers.

In this regard, Denmark ranks higher than the EU average when examining the portion of personnel who works with research and development compared to the workforce as a whole - but we are still surpassed by Sweden and Finland.

Figure 4: R&D staff per 1,000 in labour force, 1990-2000



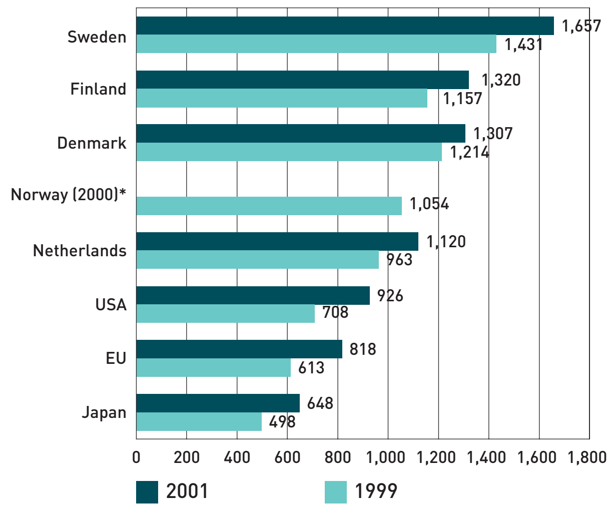
Source: OECD, Main Science and Technology Indicators, 2002:1.

But having more researchers is not enough. Denmark only conducts 0.5 per cent of the total research worldwide. This is why we need to obtain research from sources abroad.

International collaborations give Danish researchers access to the latest knowledge and technologies. But knowledge and research results are not something one simply receives by e-mail - knowledge must be exchanged in a mutually profitable collaboration. Good scientific results are therefore the only valid entrance ticket to international collaborative networks.

It is difficult to measure the quality of research directly. Therefore, so-called publication and citation analyses are used.[1]

Figure 5: Number of scholarly publications per million inhabitants, 1999/2001



Source: European Commission: Key Figures 2001, 2002.

*: National Science Indicators/Institute for Scientific Information, ISI. Reproduced in NIFU 2001.

Danish researchers do well in these comparisons, so the quality of Danish research is very high. The latest estimate of the number of scientific publications per capita places Denmark considerably higher than the EU average.

4.3 Education: Changes in demands for competencies

It is only possible to utilise the opportunities in the knowledge economy when there is access to enough persons with the right education and strong competencies. This market is stimulated by public investment in education.

The education of Candidatus (Master) graduates and PhDs is a vital channel, which leads knowledge from the universities to the rest of society. However, people with other types of higher education are also important players in the knowledge economy, especially with regard to the dissemination of knowledge. Therefore, it is essential that we educate Candidatus (Master) graduates and PhDs as well as people with other types of higher education with a high standard of academic excellence.

Education is beneficial for all of society. Companies need workers who can get the best out of technology. The public sector needs workers with the right qualifications to perform society's duties efficiently. At the same time, knowledge and education in themselves enrich the individual citizen - and promote their involvement in politics and the community. A high level of education in Denmark is therefore important in order to maintain our competitive edge and further develop our high standard of living.

The 11 Danish universities and the newly established CVUs and vocational academies all help to ensure this. The task of the universities is not only to conduct research and provide education. In conjunction with the other educational institutions, they are to continuously improve the qualifications of the working population through further and continuing education in areas spanning from languages, educational theory and the social sciences to computer science and microbiology. Another essential task is to collaborate and maintain a dialogue with companies, organisations and authorities. It is all about the exchange of knowledge, the transfer of technology and participation in the public debate.

Altogether Denmark invests more in education than all other countries. But only approximately 20 per cent of the total expenditure goes to higher education. In the countries, which invest the most in education, the corresponding share is 25-30 per cent. However, Denmark generally ranks with the other Scandinavian countries, cf. Table 1.

The calculation includes direct appropriations for educational programmes as well as appropriations for support functions and in the case of the universities

Table 1: Investments in higher education as percentage of GDP (1998)

	Higher education	
	Public	Private
Denmark	1,49	0,04
Finland	1,68	-
Netherlands	1,15	0,03
Norway	1,42	0,09
Sweden	1,49	0,17
Average*	1,06	0,29

Source: Education at a Glance, 2002.

* Average for all countries included in the OECD sample.

also research appropriations. However, the figure does not include the State Education Fund (SU), which provides student grants.

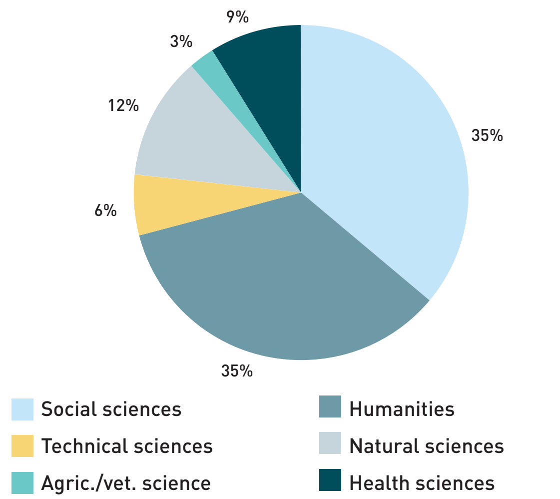
The number of students in higher educational programmes has risen sharply in recent years. In all, more than half of the adolescent in 2000 began a higher education compared to 30 per cent in the beginning of the 1980s.

In 2002, 18 per cent of the adolescent began a university degree (master degree or PhD) higher education at the universities. However, altogether only approximately 5 per cent of the adult Danish population has obtained a Candidatus (Master) degree.

A total of 105,000 students are following the research-based educational programmes at the universities. Of these, Candidatus students account for more than 53,000 or 51 per cent, while 45 per cent, or slightly more than 47,000, are studying for a Bachelor degree. To this should be added approximately 5,000 PhD students, corresponding to 5 per cent, cf. Figure 9. In addition to those following the universities' research-based educational programmes, the other institutions of higher education have 22,000 students following short-cycle higher education programmes and 75,000 following medium-cycle higher education programmes.

Both intake and the number of graduates have risen considerably in the 1990s. The rise in the number of graduates corresponds to the rise in the number of students admitted with a generational shift of six to seven years. In 2000, the intake for the university educational programmes was more than 18,000 and

Figure 6: Entering university students broken down by faculty, 2002

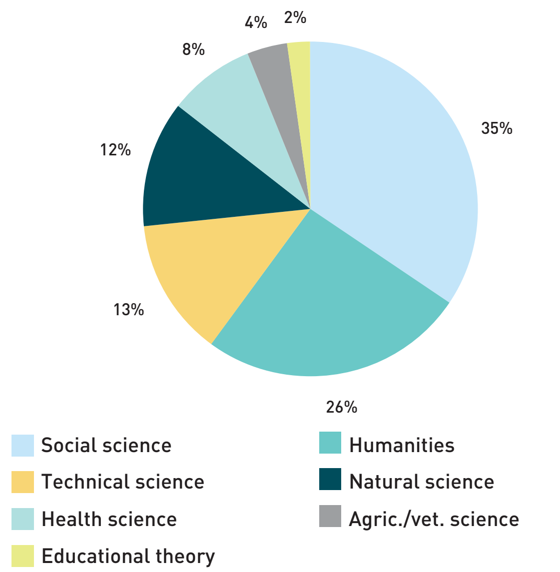


Source: Den Koordinerede Tilmelding (The Coordinated Registration System) 2002.

the number of graduates was approximately 8,600. Of these students, 70 per cent choose to study in the social sciences or the humanities disciplines, cf. Figure 6.

The universities educated a total of 8,600 Candidatus graduates in 2000. More than 60 per cent of these graduated from the social sciences and humanities.

Figure 7: Breakdown of Candidatus (Master) graduates by faculty, 2000



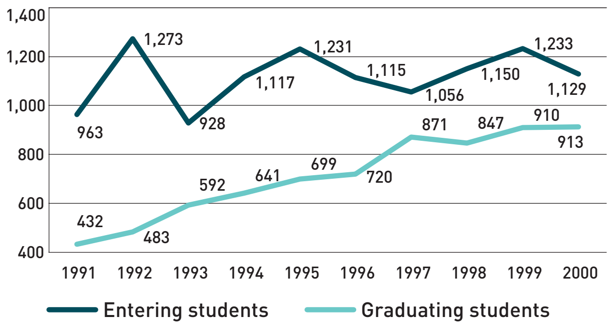
Source: Ministry of Science, Technology and Innovation.

The figures are reversed with regard to PhDs. That is, more than half of the approximately 900 new PhDs granted in 2000, were granted within the health and natural sciences disciplines.

Between 1990 and 2000, the number of PhDs has more than doubled from approximately 400 to 900 per year. In recent years, Danish universities have admitted approximately 1,100 new PhD students a year.

This figure has remained fairly stable. Both the public sector and, especially, the private sector increasingly demand PhDs in accordance with the rapid development of new knowledge-intensive industries such as pharmaceuticals and IT.

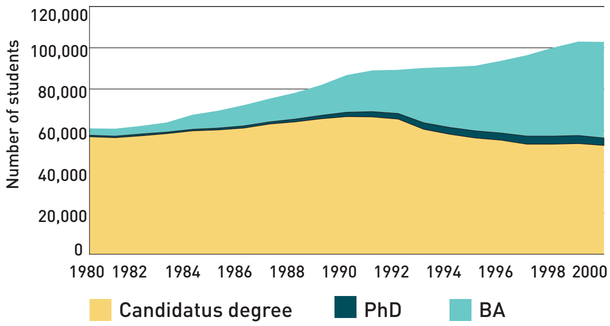
Figure 8: Entering and graduating PhD students, 1991-2000



Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

As a whole, the universities have seen a large increase in enrolment. Enrolment in Bachelor programmes began to rise significantly after 1993. Until 1993, the only Bachelor degrees were Bachelor of Science (economics) and Bachelor of Business Language.

Figure 9: Number of persons in University educational programmes, 1980-2000



Source: Ministry of Education and Ministry of Science, Technology and Innovation.

The range of disciplines available to students has changed in recent years. Some disciplines have experienced strong growth, while others have developed more moderately.

This applies to, among other disciplines, the technical sciences - especially with regard to the education of civil engineers, which stagnated in the 1990s.

In 2001, there were approximately 98,000 employees with a university education in the Danish business and industry community. This corresponds to approximately 6 per cent of the 1.5 million employed. Of these, approximately 8,000 have a degree in the natural sciences and 21,000 have a technical science education. This means that one-third of all those with a university education in the Danish business and industry community have a technical-natural science education. This corresponds to approximately 2 per cent of all employed.

Within the technical sciences, humanities and social sciences, there must also be good opportunities to maintain the competencies of the existing workers. This applies to workers in both the private and public sectors.

The development of new qualifications, technical skills and the ability to apply and develop new knowledge is essential in a knowledge-based economy. The goal is life-long learning where as many people as possible acquire new competencies throughout their careers. The tools are continuous professional up-grading, up-dating and development through the universities' continuing and further education programmes, such as Master programmes, short-cycle continuing education courses, distance education or e-learning.

In Denmark, new opportunities have been created in the last five years for continuing and further education at the universities. These programmes build upon the professional experience of the participants, while providing them with competencies at the same level as in the ordinary educational system. In recent years, practically every university discipline has established a number of different Master programmes and this activity has grown significantly year after year.

Table 2: Overview of the number of student man-years in master programmes			
	1999	2000	2001
Master programmes in total	369	505	685
Of these:			
Social master studies*	133	214	189
Health & social master studies	71	92	88
Technical & natural master studies**	137	86	168
Humanities & educational theoretical master programmes***	28	112	240

Source: Reporting from the universities to the Ministry of Education and the Ministry of Science, Technology & Innovation.

* Includes Master of Business Administration, Master of Public Administration, Master of Public Management, Master of Public Policy, Master in Management Development among others.

** Includes Master programmes in IT, Master in Management of Technology, Master of Fire Safety among others.

*** Includes Master of Learning Processes, Master of High School Educational Theory, Master of Education theory in IT, Master of Global E-Commerce, Master of Multimedia Arts among others.

Note: A student man-year is defined as a student that has paid tuition equivalent to one-year's full-time studies. A student normally completes the programme in two years, part time.

A Master programme is a one-year research-based higher education programme which follows the Bachelor level - i.e. a Bachelor degree is the admittance level. Master programmes take into account the professional experience and competencies of a student with a view to giving him or her the skills to perform highly qualified functions in companies and institutions. By 2002, a total of 63 Master programmes had been established.

4.4 Innovation and interaction: Better use of knowledge

Renewal and innovation can make for commercial success and a knowledge economy, which has a positive „bottom-line". Research results are often an important source of innovation, as is knowledge from a company's customers, cooperative partners and new workers.

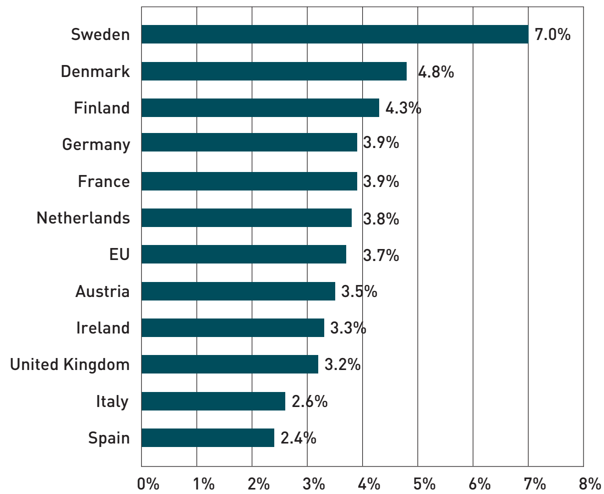
Innovation occurs when a company develops a new technology, a new manufacturing process, a new product or a new service, and introduces it to the market or into production. Innovation can also involve a company implementing a more efficient way of organising work processes.

The ability to create innovation gives an indication of how good a company's workers and management are at converting new knowledge into competitive advantages in the market. Denmark is well placed when it comes to innovation. Between 1998 and 2000, more than 40 per cent of Danish companies with more than ten employees were innovative and, for example, launched new products.

The latest figures on Denmark's innovation in the manufacturing industry in an international perspective are slightly aged - from 1996. At that time, Denmark ranked quite high. Almost 5 per cent of the turnover from manufacturing companies was invested in innovation. Denmark was only surpassed by Sweden with 7 per cent. The EU average was just under 4 per cent, cf. Figure 10.

However, the study also revealed that Danish companies were not very good at developing groundbreaking products. That is, there were new products in company product catalogues, but they were not new to the market. Other companies produced the same types of products, which indicate a limited novelty value.

Figure 10: Investment in innovation as a percentage of turnover in the manufacturing sector, 1996



Source: Community Innovation Survey (CIS2) 1996, EU.

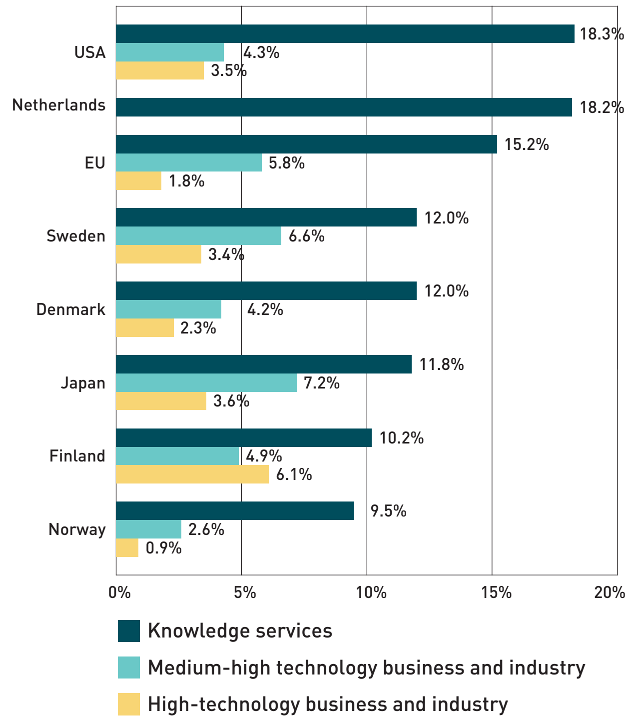
The path to new products is often winding. New knowledge is seldom created in a research laboratory and then transferred directly to a company, which subsequently develops a new product. The innovation process normally takes place in a complex interplay between many players, where access to relevant knowledge is a crucial factor.

In this respect, Danish companies are strong and good at collaborating on technology and product development. Between 1998 and 2000, more than 40 per cent of innovative Danish companies with more than ten employees collaborated with other companies on innovative projects.

Usually these companies work with other companies with which they are already acquainted, such as their customers or distributors. This applies to almost three out of four Danish companies.

Only one-third of the companies, which involve others in their innovations, choose to collaborate with Danish universities or other public research institutions. This corresponds to approximately 10 per cent of all innovative companies in Denmark with more than ten employees.

Figure 11: Valuecreated as a percentage of total value creation, most recent year*



Source: OECD Science, Technology and Industry Outlook, 2002.

* 1999 or 2000.

Technological development is an enormous task for many companies.

Some areas experience one scientific break through after another, such as in biotechnology, materials technology and IT. In these industries, this has led to a pronounced growth in the technological knowledge base at research-based companies, universities and other knowledge institutions. At the same time, there is a growing need for the other companies to closely follow the technological development in those technology sectors, which are important for their specific areas of business.

Denmark does not rank among the countries in which high-technology industries, such as pharmaceuticals, biotechnology and IT, are vital for the economy. Such industries contribute more than 6 per cent of the value added in the Finnish economy, but only 2.3 per cent in Denmark, although this is slightly above the EU average of 1.8 per cent. Nor does Denmark lead the way with regard to value added within the knowledge services. In this sector, we are below the EU average, although we are on level with the other Scandinavian countries.

This might well be because we are not good enough at commercially exploiting research results, or that the research conducted is not aimed at the needs of these industries.

Another reason for Denmark's middle position might be that research and development is concentrated in a handful of companies, just as university-educated workers are concentrated in only a few companies.

4.5 The concentration of knowledge in Danish companies

Both the private and public sectors in practically all the countries with which Denmark is traditionally compared invest heavily in research, education, innovation and IT.

These four driving forces are vital for the knowledge economy. Even though Danish companies are innovative, it is only very large companies, which have the capacity to conduct research. Thus, in Denmark the 50 largest research and development companies account for 50 per cent of the entire business and industry community's research and development.

At the same time, university-educated workers are concentrated in a limited number of companies in Denmark. This means that only a few companies have a sufficient number of knowledge workers and, thereby, the special qualifications necessary for obtaining, building up and utilising relevant new knowledge from research institutions.

Thus, the structure of Danish business and industry with many small and few large companies means that if sufficient bridge building does not take place between knowledge production and the rest of the business and industry community, then a lot of new knowledge can become concentrated in a limited number of companies.

This development is not new, but the figures in the box below indicate that from 1995 to 2000 this concentration has increased. There are slightly fewer than 2,000 knowledge-intensive companies in Denmark. This corresponds to 3 per cent of all companies with five or more employees in the private sector. These 3 per cent employ two-thirds of all knowledge workers.

Knowledge-intensive companies in Denmark

The Ministry of Science, Technology and Innovation in conjunction with Statistics Denmark has studied the number of knowledge-intensive companies in Denmark. In this context, a knowledge-intensive company is a company with a large share of employees with a university degree (master degree or PhD) higher education.

The study identified companies with at least five employees with a university degree (master degree or PhD) higher education or a PhD. As an additional factor, the employees with this educational level had to constitute at least 10 per cent of all employees in the company.

- In 2000, there were 1,819 knowledge-intensive companies in Denmark. This represents 3 per cent of all companies with five or more employees. These few companies employ two-thirds of all knowledge workers in Danish business and industry.

- In 2000, 818 companies had been knowledge-intensive companies for at least five years. These companies had a growth in number of employees of 17.2 per cent. In the same period, the number of knowledge employees at these companies rose by 34 per cent. From 1995 to 2000, 1,001 companies developed into knowledge-intensive companies.

Examples of knowledge industries – three focus areas

The IT industry, the new media and communications industry and the pharmaceutical industry are among the most obvious examples of knowledge industries in Denmark.

Together, these three focus areas account for one-third of all knowledge intensive companies, even though they only constitute a limited portion of the Danish economy. The number of employees indicates that these three areas are rapidly growing.

At the same time, the industries contribute considerably more to value creation and profit to the economy than the rest of the business and industry community. The majority of these companies manage to take advantage of the possibilities inherent in the knowledge economy and to convert them into value and competitiveness, to a greater extent than other companies.

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How the focus areas perform
The Ministry has benchmarked these focus areas that is the IT, media and communications and pharmaceutical industries, and the rest of the business and industry community. Benchmarking shows that the focus areas, with the pharmaceutical industry leading the way, perform better than the rest of the business and industry community in the parameters compared. In pharmaceuticals, profits have doubled and globalisation is four times as high as in other industries. The focus areas are also clearly in front compared to other industries with regard to investment in knowledge. For instance, the share of university educated is four times as great in the IT and pharmaceutical industries and, in the case of pharmaceuticals, R&D expenditure is 15 times as high. Furthermore, the share of PhDs among employees is higher, innovation activity is higher and the number of knowledge-intensive companies is 3-4 times as high as in the business and industry community in general. Finally, IT usage is on average greater in the focus industries than in the business and industry community as a whole.

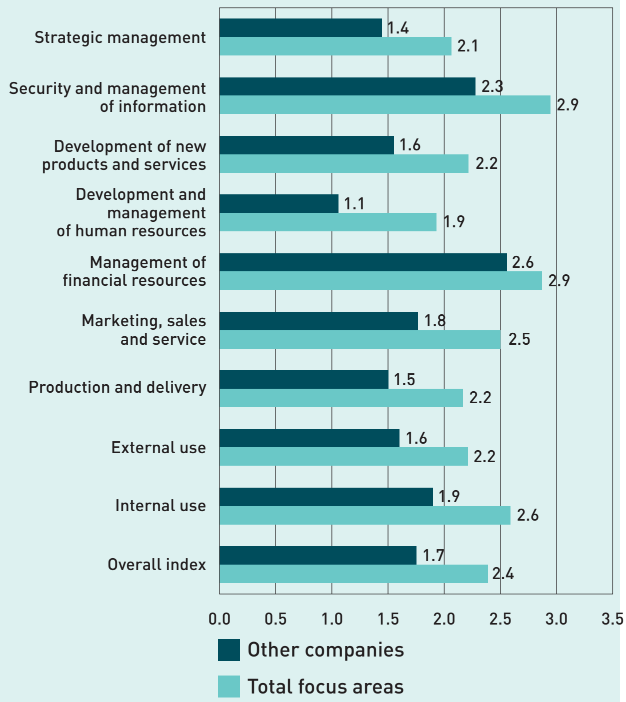
	IT	Media/ comm.	Pharma- ceuticals	Other	Private industry
Earnings (in DKK 100,000)	3.0	3.3	6.1	3.0	3.1
Globalisation	19.8%	4.2%	74.6%	18.9%	19.6%
University-educated	13.9%	6.3%	15.7%	3.7%	4.7%
R&D expenditure	2.3%	0.1%	9.7%	0.4%	0.7%
Tech./nat. sci., etc.	6.5%	0.7%	12.4%	2.1%	2.5%
PhDs	0.3%	0.1%	1.6%	0.2%	0.2%
Innovation	56.0%	38.0%	77.0%	40.0%	41.0%
Knowledge intensity	14.3%	4.3%	10.7%	2.4%	3.1%

Source: Statistics Denmark.

Notes:

- "Earnings" are value creation less pay roll costs per man-year in 1999.
- "Globalisation" is exports as a percentage of turnover in 2001.
- "University-educated" is the percentage of employees with a university education in 2001.
- "R&D expenditure" is Research and Development expenditure in 1999 as a percentage of turnover in 2001.
- Tech./nat., etc. is university-educated employees with a technical, natural science, veterinarian or agricultural science background with regard to employment in 2001.
- PhDs are PhD-educated as a percentage of employment in 2001.
- Knowledge intensity is the percentage of knowledge-intensive companies in 2000.
- Innovation is the percentage of companies with product/process innovation between 1998-2000.

Use of IT by companies in relation to business area (IT index)



Source: Statistics Denmark and Ministry of Science, Technology and Innovation.

Index score: min. = 0; max. = 4.

The three focus areas are financially strong – in spite of their size
These three industries are relatively small. When compared to the entire business and industry community in Denmark, they account for only 15 per cent of the total employment. There are 96,000 employees in the IT industry, which has a turnover of DKK 192 billion. The media and communications industry has 48,000 employees, and has a turnover of DKK 65 billion. For pharmaceuticals, the figures are 21,000 employees and DKK 41 billion in turnover.

But the financial importance of these areas has increased in recent years. For instance, the growth in the number of employees has increased by 29 per cent in the IT industries, 10 per cent in media and communications and approximately 3 per cent in pharmaceuticals between 1995 and 1999. In comparison, the number of employees in the rest of the business and industry community has only increased by approximately 6 per cent.

Furthermore, companies within the three focus areas are good at creating value. Every single employee creates on average 15-30 per cent more value than the employees in the other industries. In the IT and media/communications industries, the level is about DKK 651,000, or almost DKK 100,000 above the average for the other industries. Pharmaceuticals distinguish themselves notably with DKK 938,000 in value added per employee.

Table 3: Size and financial importance of the three focus areas

	Full-time employees 1999	Growth in no. of full-time employees 1995-1999	Turnover 2001 (DKK million)	No. companies 1999	Value creation per full-time employees
IT industries	96,241	29.0	191,742	14,132	651
Media/communications	47,602	10.4	65,153	13,106	646
Pharmaceuticals	21,094	2.7	40,926	495	938
Other industry	945,988	6.2	1,850,251	208,415	564
Private industry	1,110,925	8.0	2,148,072	236,148	

Source: Statistics Denmark.

There are many explanations as to why these industries contribute more to the economy than the rest of the business and industry community. But one significant reason is that many of these companies focus heavily on investments in research, qualified highly educated workers, innovation and technology.

In 1999, these three focus areas accounted for approximately DKK 9 billion of the total private research and development investments of more than DKK 16 billion. Thus, companies within the focus areas conduct far more research than the rest of the business and industry community. Together they conduct more than half of all private research and development in Denmark. For instance, the pharmaceutical industry's R&D investments correspond to approximately 10 per cent of turnover. For business and industry as whole, R&D investments account for less that 1 per cent of turnover.

There are also major differences between companies in the three focus areas and other companies with regard to innovation. For example, more than two-thirds of companies in the pharmaceutical industry with more than ten employees launched new products or introduced improved production methods in 1998-2000, while far less than half did so in the rest of the business and industry community. For IT companies, considerably more than half have made new innovations, which is still a high figure. The media and communications industry more closely resembles the rest of the business and industry community in that approximately 40 per cent of companies have made new innovations.

The three focus areas are also far ahead with regard to the average level of education of employees. In pharmaceuticals, approximately 16 per cent of employees have a university education. Correspondingly, approximately 14 per cent of employees in the IT industry have a university education, while the figure for media and communications is approximately 6 per cent. In general, the level of education in the focus areas is quite a bit higher than in the rest of the business and industry community, where only slightly more than 5 per cent of employees have a university education.

The focus areas also have an increased focus on IT usage and are better in many ways at taking advantage of the opportunities inherent in IT than the rest of the business and industry community. For example, they have more high-speed Internet connections. Furthermore, these companies are better at underpinning the development of new products, competence building and knowledge sharing with IT and the Internet.

4.6 IT and telecommunications: Penetration and usage

IT and telecommunications are essential for the development, dissemination and application of knowledge both in the knowledge society as a whole and in the Danish knowledge society in particular. Furthermore, the IT and telecommunications industry can independently contribute to growth.

Internationally, Denmark is performing well in IT and telecommunications. For instance, Denmark is a leader with regard to the newest Internet technologies. We also have a very well developed infrastructure and subsequently good conditions for utilising our total investments in knowledge. The challenges of the future can be found in the actual application, utilisation and profitability of IT and tele-communications.

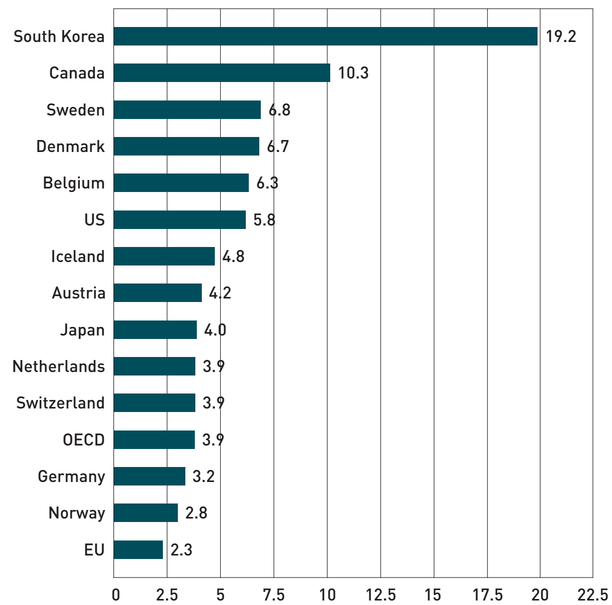
Infrastructure

Today, Denmark has the highest Internet penetration levels in the EU. Of all Danish households, 65 per cent have access to the Internet compared to an EU average of 40 per cent. In 2001, 90 per cent of all companies had access to the Internet and practically all-public institutions have web access.

An increasing number of Danish households and companies are gaining access to high-speed broadband connections. As of mid-2002, approximately 14 per cent of Danish households and small and medium-sized companies had access to a high-speed Internet connection in the form of ADSL (Asymmetric Digital Subscriber Line), cable modem, optical fibre or FWA (Fixed Wireless Access).

Compared to other countries, Denmark not only has many Internet connections, the share of high-speed connections is also large and rapidly increasing. As Figure 12 shows, Denmark, with 6,7 per cent of the population as of mid-2002, has one of the highest penetration levels among European countries surveyed, closely followed by Belgium and Iceland. In the figure, Denmark is compared to countries with high penetration levels for high-speed Internet access.

Figure 12: Spread of high-speed access to Internet* per 100 inhabitants, mid-2002



Source: OECD - December 2002.

*ADSL, cable modem, FWA and LAN.

Although high-speed access is still in its infancy, it has tremendous strategic importance for the development of IT. It is therefore vital that the prices of telecommunications services are competitive and that they are provided to consumers on free and equal competitive terms.

The companies and their employees

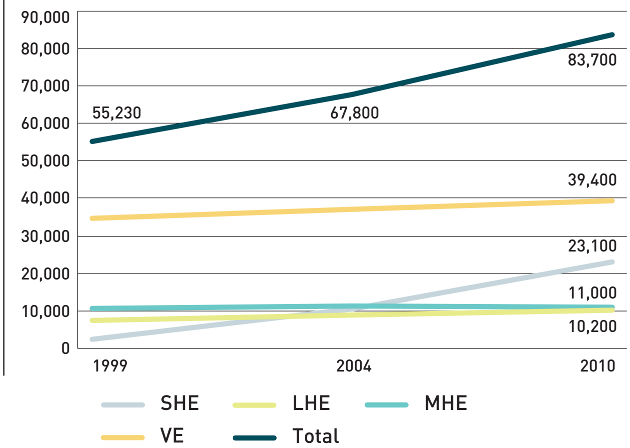
High-speed and high reliability are a prerequisite for utilising IT at a more advance level. For example, it gives companies the opportunity to integrate their business processes electronically. Among other things, broadband connections are a prerequisite for the Danish business and industry community to be able to utilise the potential inherent in IT and thus save time and money. Altogether, one-third of all companies with Internet sales have integrated this function with their other IT systems.

There are many examples of how IT creates business opportunities. For instance, furniture manufacturers can use simulation programmes to design new furniture and pharmaceutical companies can integrate IT into their health products to improve patient treatment. Companies can also utilise IT for e-learning to improve employees' competence levels.

The Ministry of Science, Technology and Innovation has developed an IT Index which shows that Danish business and industry overall has extensive IT equipment at its disposal, but that IT investments generally are deployed at a relatively low level. Among other things, the IT index suggests that there is still a great potential for IT usage in Danish business and industry with regard to supporting and creating digital coherence in business processes from purchasing over production to sales.

However, more advanced IT usage requires employees to possess good IT competencies. From 1999 to 2010, the number of Danes with an IT education will increase by almost 30,000. By 2010, more than 80,000 will have an IT education in Denmark and over 10,000 of these will have a university degree (master degree or PhD) higher education in IT.

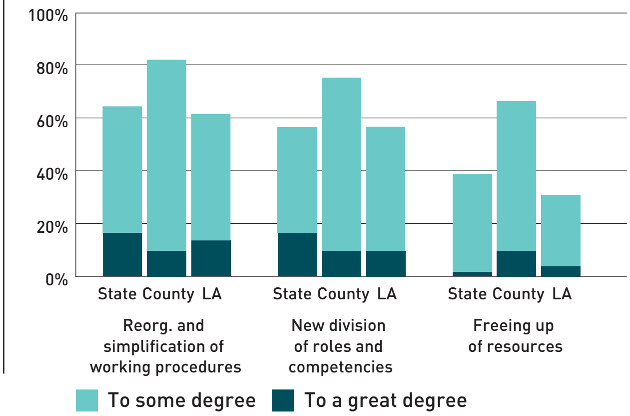
Figure 13: Expected trend in offerings of IT educational programmes broken down by educational level,* 1999-2010



Source: Danish Ministry of Education, Danish Ministry of Information Technology and Research, et al.: "IT-arbejdskraft og -uddannelser - udbud og efterspørgsel" (IT Personnel and Qualifications - Supply and Demand), 2001.

* Maintenance of 2000 intake, graduation percentage, etc.

Figure 14: Changes in performance of duties because of digitalisation projects, 2002



Source: Statistics Denmark: Den offentlige sectors brug af IT (The public sector's use of IT), 2002.

The citizens

One-third of the Danish population uses the Internet daily - the higher one's education, the greater one's Internet usage. More than half of those with a higher education use the Internet every day.

In the last two years, the number of mobile phone subscribers in Denmark has increased significantly. At the end of the 2nd quarter of 2002, there were approximately 4.2 million Danish mobile subscribers. This corresponds to 84 per cent of households having a mobile phone, which is a very high level of mobile telephony penetration compared to many other countries.

The public sector

The Ministry of Finance has calculated the total projected government investment in IT in 2001 to be DKK 1.3 billion. Administrative systems constitute the largest posts with 40 per cent of the total investment. The Internet also represents one of the largest investments, since it is expected that 27 per cent will be reserved for this area.

Citizens and companies benefit from the large investments through the advantages that are inherent in digital administration. But in addition to this, these investments also influence the internal organisation of authorities. Often, such projects lead to new and simpler work routines. This takes place to some or to a great degree at 6 in 10 authorities.

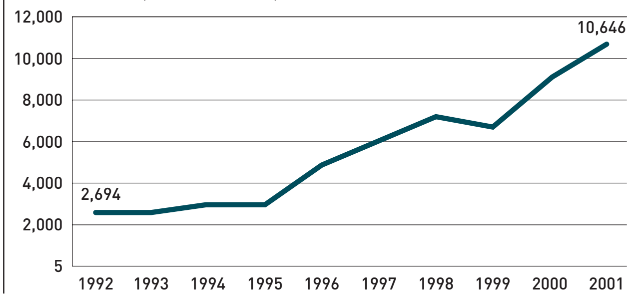
However, there are not always profits to be gained. In more than half of the cases, the IT projects did not result in freeing up resources for other tasks. In some cases, this is because it takes some time for the savings to become apparent. But the figures also reveal another factor: The authorities which change work procedures and competence distribution in connection with digitalisation projects save resources more often than those who do not. In other words, IT makes a difference, but seldom on its own.

The telecommunications industry

The Danish telecommunications market is a market in growth with ever increasing competition and consumption of telecommunications services.

Investment in the Danish telecommunications sector has increased significantly since the liberalisation process began in 1995. In 2001, the total investment was more than three times higher than in the years before 1995. Thus, liberalisation has formed a basis for growth in the sector, which is especially

Figure 15: Investment in the telecommunications sector, 1992-2001 (DKK million)



Source: Danish National IT and Telecom Agency.

characterised by increasing investments in the development of networks and services.

The total turnover in the telecommunications sector has almost doubled from 1995 to 2001, even though prices for telecommunication services have fallen during that period. Thus, the increase in turnover reflects the incredible growth in consumption of telecommunications services. The highest growth has been in the areas of data communication, Internet and mobile telephony.

[1] Publication analyses calculate the number of scholarly articles which are printed in recognised scientific journals. These journals evaluate the quality of each article. Therefore, the number of articles printed acts as a measure of the quality of the research.

Citation analyses count how many other articles a given article refers to. This is based on the theory that the more research builds on a given result, the higher the quality of this result.

> Stronger management and better interaction between institutions should promote quality and adaptability in the knowledge system.

> New combination possibilities and a stronger research base should ensure relevance and improve the academic level of educational programmes.

> A new system for research counselling should improve coherence in appropriations and counselling on research and innovation.

> New collaboration models for research and innovation should improve the interaction between knowledge institutions and the business and industry community.

> A new and more coherent structure of technology transfer should promote the commercialisation of research results.

> Improving IT development should promote productivity in all sectors of society.

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5.1 Challenges facing the Danish knowledge system

Henceforth, the development in the global knowledge economy will place new demands on all parts of society. IT and telecommunications will expand in all sectors of society and become integrated as a natural element in the way we communicate, work, and go to school and shop. Knowledge work is becoming more important and those with a higher education will continue to gain ground in the labour market. Companies will meet increasing competition for knowledge content in products and work processes. Networks between customers, distributors and between companies and knowledge institutions will receive new strategic importance - both regionally and globally. Knowledge will increasingly become a competitive parameter, and private players will increasingly compete with public knowledge institutions in a global knowledge market.

The challenges in Denmark - in brief

We must:

> Improve the overall level of education and recruit highly qualified knowledge workers for both private companies and knowledge institutions.

> Prepare Danish companies and knowledge institutions for a global knowledge market with increased competition for investments and knowledge work.

> Create better conditions for growth for knowledge-based production.

> Increase investments in knowledge.

> Convert Danish IT usage into increased efficiency, productivity and competitive strength.

Better interaction and concrete collaboration between companies and knowledge institutions is a very important focus area in the effort to meet these challenges.

The Danish knowledge system is basically in good shape, however active, rational and timely management of several challenges can make it even better. These are long-term challenges, which cannot be solved during a single Budget term or with a single knowledge strategy. To begin with, the political responsibility for Danish universities, research and innovation policy and the IT and telecommunications industry are gathered under one roof with the establishment of the Ministry of Science, Technology and Innovation a little over a year ago. The goal is to concentrate our strengths and create more coherence in several of the areas that form the foundation of the knowledge society.

Subsequently, the Government has initially identified six focus areas. Good results in these areas will strengthen the Danish knowledge system's position as one of the world's most competitive systems. Specifically, these are:

> Reforms of knowledge institutions
> Competencies and human resources
> Coherence in appropriations and counselling
> Interaction between knowledge institutions and the business and industry community
> Commercialisation of research results
> IT and telecommunications.

These six focus areas contain a large number of specific reforms and initiatives which the Government either has implemented or is in the process of initiating, and which comprise the Government's knowledge package. The knowledge package represents an investment in Denmark's future. This is the first phase of a long haul, which the Danish Government will maintain in coming years.

5.2 Reforms of knowledge institutions

Knowledge institutions and the educational system should produce and disseminate knowledge and provide education of a high quality and a high level of academic excellence. Furthermore, Danish knowledge institutions should increasingly be able to be even more forthcoming towards society - nationally as well as internationally.

Flexibility and adaptability

In order to achieve these goals, a number of reforms of knowledge and educational institutions are needed. These reforms should help improve the exchange and communication of knowledge, while at the same time increase the use of new knowledge. Furthermore, these reforms should make it possible for knowledge institutions to continue to perform the various duties and meet the many challenges set by the knowledge society.

Generally, the goal is better institutions and better interaction between institutions as a basis for better education, knowledge production and utilisation of the knowledge created by knowledge and educational institutions.

Therefore, Danish knowledge and educational institutions should be more flexible and should be able to adapt to new duties and challenges. The institutions should be able to receive, produce and convert knowledge at a high level of academic excellence and they should provide high quality educational programmes.

Furthermore, knowledge and educational institutions should be strong academically and should utilise their resources efficiently. They should have a healthy economy. The individual institution should to a greater extent interact with other knowledge institutions and should take the competency needs of society as its point of departure.

Securing the future of knowledge institutions

Knowledge and educational institutions should collaborate constructively with each other and with other parts of society to a much greater extent than they do today. This requires stronger management, which can prioritise strategically.

Therefore, the Government will change the rules to give institutions greater self-management and freedom. The purpose is to strengthen and future-orient the institutions so they can meet future demands for increased openness, flexibility and interaction with society.

Better framework for interaction with knowledge institutions

Knowledge and educational institutions should be strong, self-sustaining and able to utilise their strengths in collaboration with each other and society. This requires a new, coherent and development-oriented way to manage the sector.

The starting point for this new framework is self-management for the individual institution and greater focus on the institutions' results and core functions. Managing output and focusing on main tasks should give more freedom to institutions and consequently strengthen their ability to improve quality.

At the same time, the framework should create better opportunities to transfer knowledge and technology between knowledge and educational institutions and between them and other players, i.e. companies and authorities. Knowledge institutions, users, recruiters and other cooperative partners and stakeholders should interact appropriately.

The goal is to utilise the knowledge produced as broadly and optimally as possible. Therefore, knowledge institutions should to a higher degree listen to the desires of consumers of knowledge and educated employees - and act accordingly.

The Government has initiated a number of reforms designed to fulfil this goal.

The university reform

In conjunction with the Social Democratic Party and the Christian People's Party, the Government has entered into a political agreement on a reform of the university sector. The goal is better communication of knowledge from universities, targeted development of new knowledge and competencies along with an improved utilisation of this knowledge.

The new University Act, which will follow the agreement, should give the universities greater freedom to continuously improve research and education in close collaboration with other parts of society. In this way, the universities are obliged to collaborate with society on the exchange of knowledge and the transfer of technology.

The university reform gives universities a more powerful management, which can prioritise and formulate strategic targets based on the knowledge society's demands to the individual universities. Greater decision-making powers, efficiency and development are key prerequisites for dynamic

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universities, which need to be flexible in their reactions to changeable and complex demands by society.

Each university should therefore have a board of directors with an external chairperson and a majority of external members to act as bridge builders between the university and society. This strengthened management should have more liberty of action. Consequently, the new act relaxes central government control.

Furthermore, the university reform introduces a new type of performance agreement between the central government and the institutions. These performance agreements can for example contain qualitative and quantitative targets on credits, increased study completion percentages and internal follow-ups on education, teaching and research evaluations.

The performance agreements also describe the future collaboration with external partners and contain operative targets for the universities' work with quality improvements.

In conjunction with the university reform agreement, there is also agreement on giving the IT University of Copenhagen status as an independent university once the University Act comes into effect. The IT University conducts research and education at a high international level and has been able to create a dynamic collaboration with other universities as well as the IT industry. The IT University has also been a vital driving force for the development of new (cross-disciplinary) IT programmes and research in the IT sector.

The government research institute reform

The Government finds it vital that government research has the proper proportions and the correct limitations in relation to the rest of the research and educational system.

Therefore, the Government intends to implement a reform of the government research institutes. The goal is to strengthen basic research and to ensure better interaction between government research institutes and mainly universities on research, education and innovation.

The Government focuses on giving higher education programmes the opportunity to utilise the competencies of government research institutes. Henceforward, government research should therefore contribute more to teaching in the areas where the government research institutes have their special strengths. Furthermore, there should be as much employee mobility and knowledge exchange as possible between government research institutes, universities and the business and industry community.

The Government also emphasises the importance of government research concentrating on its core areas. The task is, in part, to help ensure a well-founded academic authority and counselling preparedness and, in part, to contribute to relevant knowledge development in business and industry and the public sector.

Furthermore, the research appropriations are to be distributed in open competition based on a quality evaluation. With regard to the mutual prioritisation and organisation of the research areas, the focus should be on defining government research's special action areas and ensuring high quality and critical mass.

The Government's initiatives

The university reform
The purpose is to strengthen the universities' management and to clear the way for more representatives from outside the university sector to ensure closer interaction between the universities and society regarding research and research-based education at a high level of international excellence. Furthermore, the universities' obligation to transfer knowledge and technology to society has been clarified. The Government wants to give Danish universities broader framework conditions to conduct research and education and to work closely with society. This freedom is to be achieved through self-ownership and so-called second-generation performance agreements. At the beginning of 2003, the Government will issue draft legislation on the new University Act.

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The government research institute reform
With its government research reform, the Government intends to strengthen basic research and to ensure better interaction between universities and government research institutes regarding research, education and innovation. This reform includes draft legislation for a new Act on Government Research Institutes and an examination and a concrete evaluation of each Danish government research institute with a view to reorganisation. Thus, the Government focuses on providing government research with the proper proportions and the correct limitations in relation to the other public knowledge institutions. The main elements of the reform are that institutions are to be made independent of the relevant ministry with regard to management and their research is to be evaluated continuously and independently based on uniform and recognised principles. With regard to financing, the fundamental principles are that public research funds - in addition to institutions' basic grants - should be distributed in open competition and that government research should be well founded and should not distort competition.

Reform of short and medium-cycle education programmes
As part of the follow-up on reforms of the short and medium-cycle education programmes, institutions, acting as knowledge centres, should enter into collaborative relationships more often with the regional business and industry community. Funds have been appropriated to support the development of knowledge centres where initiatives target, in part, the study environment at schools and, in part, regional business and industry. Increased regional interaction between educational institutions and companies has the additional special perspective of strengthening local interaction between education providers and the labour market, also outside large urban areas.

5.3 Competencies and human resources

The Government places great emphasis on relevance, a high level of academic excellence as well as on coherence and progression in the entire Danish educational system.

The educational system should be able to fulfil both the private and the public sector's expectations regarding employees with relevant qualifications and competencies. The system should be as flexible as possible and should ensure that vocational qualifications be obtained in different ways, at different times and at all levels.

A variety of competencies

Many companies will introduce new technologies in coming years. The continual improvement of products, processes and organisation is becoming a part of our everyday life, requiring extensive adaptation. This makes it necessary to work based on a broad notion of competency, otherwise it would be impossible to fulfil the changing needs and demands of the knowledge society on the individual employee for flexibility and adaptability.[1]

The Government intends to improve the quality, focus and academic level of the educational system from basic schooling to higher education. Companies should have better access to qualified workers at all levels.

Furthermore, the Government will ensure that more employees change jobs between companies and research and educational institutions. This should be achieved by creating a framework, which increases researcher mobility and by developing incentives and mechanisms to increase the number of researchers and other highly trained employees at smaller companies.

Finally, the Government intends to ensure dynamic mobility in the Danish knowledge system. These are ambitious goals, but the foundation is already in place: Denmark spends large sums on education, we have a long tradition of obtaining education and, last but not least, we have talented teachers, excellent institutions and a cooperative business and industry community.

The competency requirements of the knowledge society

The knowledge society's labour market increasingly demands flexibility and qualifications at a high level of academic excellence in the knowledge system.

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From 2006, the youth population will again begin to grow. Therefore, the knowledge institutions and educational system should be ready to ensure high quality and relevant educational programmes for both ordinary education and for continuing and further education.

Moreover, the growth of the Danish economy is dependent on the workforce growing and more workers remaining in the labour market. The educational system plays a vital role in this regard as well. Targeted continuing and further education and flexible ordinary education programmes should reduce dropout rates, wrong choices and extended periods of study.

It is also important that students complete the education programmes they begin. And it is particularly important that we focus on the natural sciences, where less than half the students obtain a Candidatus (Master) degree. An increase of, say, 10 percentage points in this area can significantly reduce the future lack of engineers and natural science graduates.

The Government intends, therefore, to improve and strengthen the knowledge system on a broad front with a number of initiatives which span the individual university levels.

The Government's initiatives

Elements of the university reform:

Changes to the structure of university education programmes
The structure of the university education programmes will be changed with a view to actually ensuring the implementation of the 3+2 structure consisting of three-year Bachelor programmes followed by two-year Candidatus (Master) programmes.

Modular structure of Bachelor and Candidatus (Master) programmes
A modular structure is to be implemented for all Bachelor and Master programmes to provide students holding a Bachelor degree real opportunities to choose between several relevant Master programmes - including Master programmes at other universities.

Strengthening the academic and professional level
The academic and professional level of short and medium-cycle higher education programmes is to be improved by committing the universities to enter into research affiliation agreements with Centres for Higher Education and by ensuring the knowledge centre function of the vocational academies so research results can be communicated and utilised at all levels within the educational system.

Elements of the Government's action plan, "Better Education":

Establishment of institutions for business and industry-aimed education programmes and reform of labour market education programmes
Combining Adult Vocational Training Centres and vocational schools has formed the foundation for a unified institutional structure for the business and industry-aimed basic, continuing and further education programmes, which, today, are offered by both Adult Vocational Training Centres and vocational schools. At the same time, the reform of the labour-market education programmes will be carried out, which entails a renewal of the programmes, more dynamic development potential, the ability to locally adjust the programmes and a more target-oriented utilisation of resources. The goal is to strengthen the basic labour-market relevant competency development for adults. The two initiatives will jointly ensure regionally anchored educational institutions in close interaction with companies and citizens resulting in a flexible labour market.

Draft legislation on counselling regarding choice of education and profession
The Government has issued draft legislation on counselling on choice of education and profession which should improve and strengthen education and professional counselling and thereby ensure a better and more targeted education for the individual student, also in relation to the competency needs of society.

Strengthening the natural sciences
The Government will work to strengthen the natural sciences throughout the Danish educational system, because the intake at technical and natural science education programmes is too low compared to society's need for well-educated workers in this area.

The internationalisation of Danish education programmes
The Government will work to improve the possibility of receiving recognition for real competencies attained outside Denmark. Furthermore, the Government will work towards increased mobility between the Danish universities.

A flexible educational system with excellent credit schemes
The Danish educational system should be able to fulfil recruiter's expectations regarding flexible employees with relevant qualifications and competencies. In this context, methods should be developed for evaluating relevant vocational experience as qualifying for higher levels in the higher educational system for adults.

The new political agreement on primary and lower-secondary schools:

The political agreement on primary and lower-secondary schools
Danish primary and lower-secondary schools form the foundation for all subsequent education. Therefore, the Government wants to strengthen the academic proficiency of primary and lower-secondary schools and create more space for the individual. Primary and lower-secondary schools must ensure the right foundation so that our children can be active participants in the knowledge society. One requirement is that everyone has access to these opportunities. This requires that the individual child in a primary or lower-secondary school acquires the necessary proficiencies and skills. The political agreement on primary and lower-secondary schools between the Government, the Danish People's Party and the Social Democratic Party will ensure a strengthening of pupils' academic proficiencies and skills.

Other initiatives:

Industrial PhD programmes
The Government wants to broaden the framework of the Industrial PhD programme to include the commercial, social sciences and humanities disciplines. At the same time, an extra effort should be made to convince small and medium-sized enterprises outside the Greater Copenhagen Area to initiate Industrial PhD projects as well. As a consequence of this, the Government has increased appropriations in 2003 for the Industrial PhD initiative by DKK 15 million.

The National Competency Account
Under the auspices of the National Competency Account, a comparison tool is being developed that should make it possible to follow the development of the workforce's competencies in areas which are crucial for the competitiveness of Danish society. Indicators are being developed in order to allow benchmarking with countries to which Denmark is normally compared.

5.4 Coherence in appropriations and counselling

The Government intends to increase society's benefits from appropriations to public research by reforming the research council system. All public research appropriations, which supplement basic grants, are to be distributed in free and open competition as a way to ensure high quality. Funding will go to the strongest research environments and to research in areas of special importance to society. At the same time, the reform should ensure researchers' the freedom to realise their own projects.

Furthermore, the Government has placed great importance on closer interaction between the various councils and foundations, which manage the funds for research and innovation. Among other initiatives, this is to be achieved through the implementation of a new model for management of research counselling with more room for the interests of customers and employers.

A simpler appropriations system

In October 2002, the Government parties reached a political agreement on the reform of the research council system and all the other parties represented in the Danish Parliament. In addition to research counselling, the reform also includes an agreement on the Danish National Research Foundation.

A weakness of the former system has been that research funding had become far too complicated - with a jumble of special allocations and committees, resulting in too many addresses for the applicants. Researchers have had to deal with a bureaucratic and non-transparent system. In addition, the system has been criticised for lacking overall management and coordination.

However, with the agreed reform the appropriations system is simplified and strengthened.

The new system will consist of two research councils: One funding research based on bottom-up ideas from the research community and one funding research based on top-down, political priorities. A common characteristic of the two councils is the principle of promoting diversity and quality in Danish research through open competition based on independent quality evaluation.

Both councils have an advisory and an appropriations function and both councils are headed by a board of directors. The boards of directors are comprised of recognised researchers. The board of the council founding political initiated research programmes also has research expertise from the receiving end with competencies in both public and private research, education and innovation.

Beside the two boards of directors, the new system will consist of a number of research specific councils and a limited number of cross-disciplinary programme committees to perform the ongoing operations - such as evaluating applicants.

The *Danish National Research Foundation* will remain an independent foundation with its own board of directors. The Foundation’s main task will still be to finance major research activities based on researchers’ own ideas, and to contribute to the development of “Centres of Excellence” in connection with major programmes.

The purpose of the new *Coordinating Body* is to coordinate the efforts of the two new research councils mentioned above, the Danish National Research Foundation and the Council for Technology and Innovation. The universities and government research institutes also have representatives on the committee, which additionally is to provide counselling on funding for researcher training. Thus, the Coordinating Body takes over a number of tasks previously performed by the Board of the Danish Research Councils and the Danish Research Training Council, which are both discontinued.

Quality assurance and a better overview

In addition to the research councils, a large number of public research committees under the auspices of the individual ministries have until now provided counselling on research programmes as well as offering programmes of their own. This has led to a debate as to whether competition for funding has been sufficient in all cases. At the same time, it has been difficult for the political decision-makers to gain an overview of the appropriations to research, development and innovation because these funds are stated under each ministry in the National Budget.

Henceforth, the new council system under the Ministry of Science, Technology and Innovation will evaluate the quality of all the projects in connection with the awarding of public research appropriations, with the exception of basic funding to research institutions.

This also ensures a coherent expert evaluation of research appropriations and special allocations under the individual ministries.

Stronger counselling

Another weak element in the old system is that it gradually has become unclear who is to give advice on research policy to authorities, politicians and the public. Several players in the council system have produced their own counselling on research policy regardless of the fact that it is formally the task of the Danish Council for Research Policy. In this way, inappropriate competition has arisen, especially with regard to counselling on proposals for new research initiatives in the National Budget.

The reform gathers research policy counselling in a single body, the Danish Council for Research Policy,

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which will continue as an independent expert counselling of ministers, the Danish Government and Parliament.

Six overall targets in the reform of the research council system

1. The quality of research must be ensured through open competition for all public research appropriations, which are not basic funding to institutions.

2. The organisation and structure of councils, bodies and especially programme committees must be simplified, which will also provide researchers with a better overview of application options.

3. A new research council system must have a stronger management to ensure that strategic research is implemented on its own terms and that cross-disciplinary efforts within all areas of research are considered.

4. Extensive support of basic research activities must continue to be ensured.

5. Support of strategic, application-oriented and business and industry-aimed research must also be ensured.

6. There must be a clear distinction between the body which provides counselling on general research policy topics and the bodies which distribute funding and give advice to applicants and others interested regarding applications and research-specific and scientific questions.

Coherence in counselling on research and innovation

The *Council for Technology and Innovation* was established in August 2002. The Council consists of a chairperson and eight members who represent competencies in business and industry development and innovation. The council's task is to advise the Minister on the organisation and development of the effort to strengthen the future growth and innovation of the business and industry community. The funds within the council's area are distributed by the council and by the Minister for Science, Technology and Innovation based on the recommendation of the Council.

The appropriations for innovation are used in four areas:

1. The commercialisation of new knowledge

2. Increased innovation capacity in all business and industry sectors

3. Increased mobility and improved interaction between research and the business and industry community

4. The development of a foundation for decision-making to optimise the public research and innovation effort.

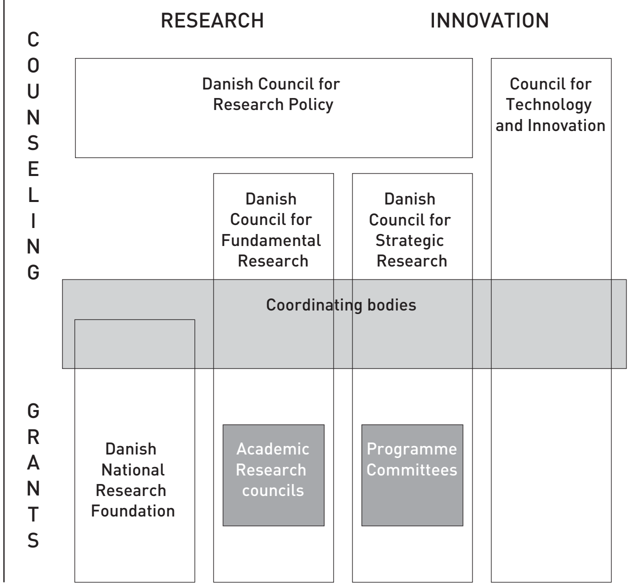
The Council's largest focus areas are the technological service institutes, centre contracts and innovation incubators.

A newer activity is Technological Foresight, which seeks to identify and debate coming technological advances that are expected to have major importance for our welfare and competitiveness. The studies are carried out with a view to inspiring and qualifying strategic decisions with a more forward-looking orientation in the innovation effort and in research.

Henceforth, the Government will require increased coherence on counselling and appropriations between the research and innovation sectors across the new council structure. Hereafter, more council will be involved in the development of strategies and in the implementation of new initiatives in the cross-fields between research and innovation.

After the research council reform, the entire council system under the Ministry of Science, Technology and Innovation will be comprised of six statutory units, which provide research and innovation funding or counselling.

Figure 1: The new council system for research and innovation



At the end of 2002, draft legislation on research counselling and changes to the Act on the Danish National Research Foundation was in public consultation. After discussion with the political parties, there may be a few adjustments and clarifications before the draft legislation is presented to Parliament.

The Government's initiatives

New legislation on research counselling
At the beginning of 2003, the Government will issue draft legislation to amend the Act on Research Counselling. At the heart of the amendment is a more coherent and user-friendly appropriations system: A new strategic research council should promote cross-disciplinary processes and ensure increased interaction between public and private research institutions. New executive boards for the free and strategic research council should simplify applicants' access to public research appropriations and should ensure increased insight into the actual application of research. A new coordinating body should improve interaction on PhD training between all appropriations bodies.

New funds for the research counselling system
With the agreement on the 2003 Budget in conjunction with the UMTS political agreement, the Government has earmarked new appropriations for the research counselling system in the order of DKK 1.2 billion distributed over a period of three years. Of this, more than DKK 700 million are set aside as unrestricted funds, while the remaining appropriations are for strategic initiatives in IT research, nanotechnology, energy research, food science research and young researchers, among other areas.

Changes to the Act on the Danish National Research Foundation
At the beginning of 2003, the Government will issue draft legislation to amend the Act on the Danish National Research Foundation. The amendments will make it possible to maintain the current appropriations level at DKK 250 million a year by permitting the investment of the remainder of the base capital. Furthermore, this makes way for greater opportunities for the foundation to enter into collaborative agreements with private foundations and companies regarding the establishment of new research centres.

The establishment of the Council for Technology and Innovation
In order to strengthen innovation policy efforts, a Council for Technology and Innovation was established in 2002. The purpose of the council is to provide counselling to the Minister for Science, Technology and Innovation with respect to developments in the innovation sector as well as to make decisions regarding several specific appropriations applications. The council was appointed according to the Act on Technology and Innovation. This Act represents the entire legislative framework for the technology and innovation sector, which was transferred from the former Ministry of Business and Industry to the newly established Ministry of Science, Technology and Innovation following the change of government in November 2001.

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5.5 Interaction of knowledge institutions with the business and industry community

Access to knowledge is becoming increasingly important for Danish companies and their ability to conduct competitive innovation.

A company's own knowledge base and employees are still its most important source of knowledge. However, the increased international competition and greatly expanding complexity of innovation means that companies have a growing need to concentrate their efforts on their own core competencies and supplement these with strategic knowledge alliances. Therefore, interaction with knowledge institutions is becoming more crucial for the development of companies.

Many types of interaction between knowledge institutions and the business and industry community

Traditionally, the most important interaction between knowledge institutions and the business and industry community has been the universities' education of Candidatus (Master) graduates. Candidatus graduates are educated based on the latest research, which they then take with them into the business and industry community when they find employment.

This is still a key element. But the development of society means that the knowledge of new graduates quickly becomes out-dated. There is a constant need to maintain competencies - primarily at work, but also through relevant continuing education. The universities, in particular, play an increasingly important role as supplier of research-based education programmes. At the Centres for Higher Education and institutions for business and industry-aimed education (vocational schools and adult vocational training centres), including vocational academies, continuing education programmes are being expanded and improved.

To this should be added the fact that the necessary knowledge can be so complex or can develop so quickly that companies need to be in direct contact with the relevant knowledge institutions. Otherwise they cannot secure themselves the latest knowledge in their specific focus areas.

Collaboration between the business and industry community and knowledge institutions is therefore far more varied today than previously. It covers much more than education, such as interaction on research and the commercialisation of research results.

Examples of different types of interaction between knowledge institutions and the business and industry community

Interaction on human resources

> Companies employ Candidatus (Master) graduates from universities or other educational institutions.
> Companies have their employees take part in research-based continuing education.
> Researchers change between public and private employment.

Collaboration on research

> Companies sponsor buildings, equipment, research, research positions, development work, development employees, etc.
> Companies requisition research and development from knowledge institutions.
> Companies and knowledge institutions collaborate on financing research and development.

Interaction on the commercialisation of research

> Publicly employed researchers establish a new company based on own research.
> Knowledge institutions obtain patents and sell the right to use them in the form of licenses.

Other

> Companies participate in research conferences.
> Companies read scholarly articles.
> Researchers and employees in companies build personal networks.

Collaboration between the business and industry community and knowledge institutions can be both form and informal. Knowledge is not only transferred through formal research collaborations with contracts and money between the parties. Also informal relations, e.g. between the individual researchers and employees in private companies, are important for the exchange of knowledge.

Limited interaction on research and innovation

Collaboration between the business and industry community and public knowledge institutions is not as highly developed in Denmark as in many other Western European countries. Which means there is a risk that we are not as capable of converting our investments in research and development into growth in business and industry.

However, there is every indication that more companies will need to collaborate with universities and other knowledge institutions. Thus, there is potential for greater interaction between business and industry and the research communities. But this requires a coherent effort that deals with the various challenges, which characterise such collaborations:

Focusing and collaboration on research, technology and innovation: Several studies suggest that improved interaction requires greater targeting of public investments in research, technology and innovation. Many companies experience that the effort is too spread out and that it is only to a limited extent carried out through dialogue and collaboration with business and industry.

Collaboration on research and development: Especially small and non-research-intensive companies have difficulties establishing collaborations with knowledge institutions on specific research and development projects.

Researcher mobility: The mobility of researchers between the public and private research sector is an essential prerequisite to the spread of knowledge and competencies from the public research sector to the private sector. The mobility of researchers is not low in Denmark compared with a number of other countries. But if we are to continue to strengthen this interaction, it is necessary to spread out research competencies to even more companies than today - especially to small and non-research-intensive companies.

Research-based continuing education: Knowledge and competencies become out-dated at a growing rate. Also among the highly educated, there is an increasing need to supplement the knowledge obtained via education. This can be difficult, however, because Danish universities play a limited role with regard to continuing education.

New models for interaction

Denmark needs academically strong knowledge institutions where e.g. universities conduct highly qualified research and educate talented graduates. However, there is also a need for knowledge institutions, especially universities and government research institutes, to collaborate to a greater extent with the rest of the world. Knowledge institutions should be aware that their knowledge is applied in other ways than through education.

The Danish business and industry community is innovative, even though only a limited number of companies are research based and conduct their own research on a large scale. Thus, it is only a relatively small group of companies which speak the language of the universities, while a large portion of Danish innovative companies have no close connection to research institutions.

Therefore, we need new models for collaboration between research and the business and industry community. These models should reflect the highly varied needs of Danish business and industry. In addition to the few research-intensive companies, there is another much larger group of development-oriented companies, which are experiencing an increasing need for new knowledge - especially application-oriented research and new technology.

The Authorised Technological Services Institutes (GTS Institutes) are very important for these companies, which are also a new target group for universities and government research institutes. GTS institutes also play a vital role for companies with very limited knowledge needs, but which sometimes run into technical problems or develop a need for new qualifications among their employees.

More and better interaction between knowledge institutions and the business and industry community is not only the key to new innovations and competitiveness. It can also bring new inspiration out to research environments and give public researchers direct access to test new technologies and study the scientific development in areas where the business and industry community leads the way.

> ***The Government's initiatives***
>
> *New innovation consortia*
> In connection with the 2003 Budget, the Government has appropriated DKK 101 million to a new initiative - "innovation consortia." Innovation consortia are specific knowledge initiatives between companies, research institutions and the technological services that develop new technologies, which can strengthen companies' product and services development.
>
> *Pilot scheme allowing 150 per cent tax deductions for research collaboration*
> A pilot scheme has been initiated which allows companies a 150 per cent tax deduction of costs incurred in connection with research projects funded in collaboration with research institutions. In spring 2003, the Government will evaluate the scheme.
>
> Also in spring 2003, the Government will submit an action plan for strengthening interaction between the business and industry community and knowledge institutions (cf. section 6.2).

5.6 Commercialisation of research results

More of the results from public research should find its way from laboratories to the open market.

This is why the Government intends to create better conditions for the commercialisation of research. A free and efficient market for research-based knowledge and intellectual property rights needs to be developed. This refers, in part, to better incentives and a more flexible framework for innovative researchers and institutions and, in part, to a strengthening of the infrastructure for the transfer of knowledge and technology. The goal is a better structure, which gives innovations a push forward and forms new ties between researchers and business people.

Several paths from research to business

Danish researchers and research institutions have a responsibility for passing on their results and inventions - not only to colleagues in the academic world, but also to the benefit of society as a whole.

New advances from public research should be converted into new products and services to create a foundation for new workplaces and increased competitiveness.

The commercialisation of knowledge and results from public sector research can take place in two fundamentally different ways. It can take place through the establishment of new knowledge-based companies, e.g. when researchers start up their own entrepreneurial businesses. And it can take place through the sale of licenses and patents.

The way knowledge institutions and innovation incubators handle their work has been criticised by the business and industry community. The Government has, therefore, initiated a service inspection of the entire sector for the commercialisation of research results.

Higher expectations for the commercialisation effort

As of January 2000, the Act on Inventions at Public Research Institutions (the Research Patent Act) has created new incentives for patenting and the commercialisation of research-based inventions.

The main principles of the act are:

- Public research institutions, just like private companies, can acquire and utilise the rights to their employees' inventions.
- Both researchers and institutions receive part of the income when new inventions are utilised commercially.
- The institution has the contract rights in connection with inventions when entering into agreements on research collaboration, which ensures companies an unambiguous contract partner.
- Patent rights can be paid for with shares to promote the establishment of new companies.

To further the implementation of the Act, a total of DKK 58 million has been earmarked in the financial period 2000-2003 for the competency development and patent costs of institutions.

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The initial experience suggests that the new Act has kick-started the patenting effort. Most of the knowledge institutions have developed internal patent policies. The number of patent applications is on the rise and patent rights are now becoming a permanent component of the institutions' collaborative agreements with business and industry.

At the same time, new competencies with regard to patents and licenses are being developed via five socalled patent consortia, which act as professional networks across universities, government research institutes and hospitals.

The five patent consortia

At many institutions, the Research Patent Act has meant that both heads of research and administrative employees need to acquire new skills. The five cross-institutional patent consortia serve as a forum for competency development with regard to patent and licence agreements in separate fields:

> Biotechnology - health - medicotechnology
> Biotechnology - foods - agroindustry
> IT and telecommunications - electronics - measuring technology
> Manufacturing technology - materials - construction - consumer goods
> Energy - environment - transport - supply.

Patent consortia arrange joint patent courses and publicity campaigns. They also obtain knowledge on patent and licence agreements from abroad. A manual for working with patents has been developed, as has a national information site (www.techtrans.dk) and agreements have been entered into regarding the international patent database "Derwent" and the Internet exchange for inventions "yet2com".

At most institutions, work with patents and licensing is still in the developmental phase - and not yet free of teething problems.

The business and industry community has high expectations that the public research institutions should handle an increasing number of collaborative projects and licence agreements in a professional manner. However, it is doubtful whether all knowledge institutions are able on their own to live up to this growing burden. Many lack the necessary competencies - especially to market patent rights and provide inventors with professional assistance. At most institutions, only one or two administrative employees are responsible for the task, and often they are expected to fulfil a number of other tasks as well. At the same time, the institutions emphasise that the current regulations provide too little freedom and too few incentives to become involved in new companies.

New companies often need liquid capital in the start-up phase. This is why public research institutes today can accept shares in companies with limited liability as an alternative to cash payment for patent rights. However, many start-ups are established as private companies, which is why institutions would also like to be able to accept equity even in such companies. Similarly, there can be a need for a freer framework to act as co-owner in new companies by contributing value, also in the form of office space, equipment, personnel or non-patentable knowledge.

New perspectives for innovation incubators

Innovation incubators and science parks play a vital role for the establishment of new knowledge-based companies.

Denmark has been a little slower to gear its efforts towards the high technology and innovative entrepreneurs than countries such as Finland, the USA, Israel and Canada. The innovation incubators were established in 1998. And they have been the most important source of assistance for high technology and knowledge-based entrepreneurs ever since.

Innovation incubators have mediated public appropriations to entrepreneurs in the order of approximately DKK 100 million annually. They have already led to promising results. For instance, innovation incubators have managed to attract almost twice as much private investment capital as public sector capital.

Several roads to new companies

Accip Biotech A/S is a start-up company founded by Søren Gregersen, doctor and diabetes researcher at Aarhus University Hospital. Søren Gregersen has developed equipment that automates the isolation of cells - more specifically a camera connected to a computer that controls a dropper.

Østjysk Innovation in Aarhus has helped to develop the idea. A prototype has been made, the patent application has been sent and market analyses have been conducted. These efforts have helped to convince private investors about the potential of the idea, also in areas other than diabetes. The product was marketed in autumn 2002.

Alight Technologies A/S is a new company founded by researchers from the COM - Centre for Communications, Optics and Materials at the Technical University of Denmark (DTU). The researchers have developed a miniature laser with promising applications in, among other areas, communication and medical diagnostics. The Danish Investment Fund has invested venture financing in the company while DTU has invested its rights to the inventions in exchange for 15 per cent of shares.

Up to now, the innovation incubators have been geared more towards helping individual entrepreneurs than assisting research institutions to evolve and commercialise new inventions. Today, several innovation incubators have a network and a corps of consultants, which can fulfil such duties also for universities and other public research institutions. Generally, the current spread of resources among eight innovation environments has actually limited the possibility of building up specialised competencies in areas which reflect the individual knowledge institutions' academic profile.

At the same time, several innovation incubators have expressed that the universities' commercialisation strategy is too focused on patenting. Their perspective is that this has limited the number of new innovative entrepreneurs.

In the future, furthering the commercialisation of research results would require closer interaction between the different players - with regard to both new companies and the sale of licenses to the established industry.

In the summer, the Government will present its new policy for the commercialisation of research results as part of the upcoming action plan for strengthening the interaction between the business and industry community and knowledge institutions. It will include a proposal for a new structure for technology transfer and for greater degrees of freedom for commercialisation efforts at public knowledge institutions.

The Government's initiatives

New focus on innovation incubators
With the passing of the 2003 Budget, the Government has appropriated DKK 225 million over a three-year period to the continuation of the innovation incubator scheme. This will also pave the way for a reorientation of the innovation incubators with increased focus on interaction with public research, on the one hand, and with private investors, on the other. Furthermore, the initiative is expected to concentrate on fewer units.

Technology transfer - biotech-health
As the first step in a new commercialisation policy, funding has been earmarked in the Budget for the development of a pilot project involving a technology transfer unit for biotech-health in the Greater Copenhagen Region. The purpose of the unit is to improve interaction between the biotechnological research and the industrial sectors in the Øresund region. Furthermore, it is to stimulate the commercial utilisation of the growing number of research patents in the biomedical industry in particular. This initiative, which is formed under the so-called Regional Growth Environment, is provisionally set to run from 2003 to 2005. To this end, a special budgetary appropriation in the order of DKK 5 million has been earmarked.

5.7 IT and telecommunications

IT and telecommunications contribute to the communication and dissemination of knowledge in society.

The digital infrastructure is essential to provide citizens, the business and industry community and the public sector with access to new technology, electronic communication and the exchange of knowledge.

The infrastructure ensures that new knowledge is quickly made accessible to everyone. And the way we utilise IT influences how good we are at obtaining, utilising and communicating knowledge in the private and public sectors.

Thus, the spread and usage of IT and telecommunications is of great importance for the development of the knowledge system.

In recent years, both the private and public sectors have invested great sums in IT and telecommunications. It is now time to ensure that we get the most out of the many investments, so IT and telecommunications can contribute to increasing growth in the business and industry community and to reforming the public sector. The framework conditions for the future development need to be set.

A leading IT nation for everyone

In many ways, the liberalisation of the telecommunications sector in Denmark has resulted in an efficient market with a high level of competition. This ensures telephone customers more advanced services, greater choice and lower prices. Both the total turnover of the market and the total investments have already increased significantly due to increased competition and increased consumption of telecommunications services.

Price is one of the major barriers to the utilisation of IT and telecommunications. Prices for fixed-line telephony have dropped by more than 20 per cent since 1998, which signifies the collapse of this particular barrier. At the same time, we have achieved more than twice as many broadband connections in just one year.

The ability of business and industry to create value via IT and telecommunications is important for Denmark's competitiveness. Here, too, Denmark stands strong in that IT statistics show that the Danish business and industry community has embraced new information technology.

Danish employees also have more PCs and more Internet connections at home. This is due to, among other initiatives, the home compute scheme. This development has led to greater flexibility and freedom of choice in working life. At the same time, the Danes' IT knowledge has also increased.

The IT sector is one of the largest focus areas in the knowledge society. The companies do somewhat better than the Danish business and industry community in general when examining the factors, which influence the exchange of knowledge, which are earnings, globalisation and the number of employees with a university education.

Furthermore, Danish companies increasingly invest in IT and telecommunications research. The biggest increases can be seen in the software industry.

The public sector has also embraced new communication technology. All through the 90s, a considerable effort has been made to provide citizens with easier access to the public sector. All departments, local authorities and counties have websites. In the mid-1990s, self-service systems began to appear. Electronic commerce in the public sector was also debated at the time.

Challenges for the development of the infrastructure

One significant precondition for a positive development is an efficient telecommunications sector where services are provided to Danish consumers on free and equal competitive terms. That is, a market characterised by investment in the development of services and infrastructure.

In the future, it will also be essential to ensure a market with free and equal competition so citizens, companies and public authorities can have freedom of choice and an accessible, efficient, secure and inexpensive infrastructure. In this context, one special challenge is to ensure honest competition among providers in the broadband market.

However, the infrastructure is largely in place. The spread of IT is well underway, thus the focus is now

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turning towards telecommunications services, which increasingly are a competitive parameter and a path to new income for telecommunications companies.

New advanced telecommunications services can contribute to improving the Danish knowledge system. For instance, wireless technology can increase mobility.

The Government therefore finds it essential that the Danish telecommunications policy helps to layout the framework for the development and spread of advanced services.

Challenges for Danish business and industry

The demand for innovation and new creative ways of thinking is not only a challenge for companies in the IT sector. The service industries and the more traditional manufacturing industries have also shown a need to utilise new IT and telecommunications products. It is therefore essential that the task of developing new information technology, tailored software and market-oriented IT products be handled by the IT industry in close collaboration with the other sectors and relevant knowledge institutions.

The increasing demand for qualified workers puts pressure on the resources which are earmarked for continuing and further education, both for providers and users. At the same time, it is very important for companies' competitiveness to reduce the time it takes for the latest knowledge to enter the market in the form of innovative products and services. Thus, there is a need to examine how access to new competencies can be improved and made more efficient.

There is a considerable potential in utilising the Internet as a media for learning and competency development, and for creating the need for competency development and training courses. Knowledge quickly becomes out-of-date, thus it is vital that all employees continue to educate themselves and are ready to adapt in the shortest possible time frame. E-learning is a key tool in this context.

Challenges for the public sector

The public sector faces a number of challenges if the desire for e-government is to become a reality.

The overall vision is that IT must be utilised systematically to create a higher level of service and efficiency in the public sector. This requires new business processes and organisational reforms both in the public sector and across the boundary between the public and private sectors.

In 2001, a board of directors was formed for the e-government project, a Digital Task Force under the auspices of the Ministry of Finance and an IT centre at the Ministry of Science, Technology and Innovation. This was done to strengthen the effort to develop e-government and to meet the demands for new business processes and organisational reforms.

The new business processes and organisational reforms cut across the traditional organisational divisions. This requires technology solutions designed to support collaboration and the exchange of data.

This is vital for all of society. The information must be located where it is needed. A coherent IT system can help to ensure this. Another prerequisite is efficient management and presentation of data.

IT architecture plays a central role in this context. IT architecture is the design of technology solutions so they live up to specific business objectives, in other words, the principles, demands, limitations and guidelines for IT systems.

Work on IT architecture affects all of society. Coherent and efficient IT systems ensure an effective interaction between society's institutions, which, in turn, ensures that the information is available where it is needed.

A vital element in working with IT architecture is the integration of IT systems. One prerequisite for IT integration is common standards for the exchange of information. This ensures that the information sent from one IT system can be more easily utilised in other IT systems.

The visions for Denmark's development as a knowledge society and for an efficient e-government are also about security. It is difficult to utilise the technological possibilities better without securing the IT values against destruction and loss.

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IT security must therefore be in good working order. Functions which are critical to society, e.g. in the health services sector and gas and energy supply, must be secured. And the Government will also work to instil in citizens and companies a fundamental trust in information technology.

An essential element in this regard is the digital signature. In establishing electronic services, which support digital signatures, public administration will also be able to create more efficient work procedures.

The Government's initiatives

Regulation of the telecommunications market
Regulation of the telecommunications market is to ensure the presence of real competition. In fields where competition functions well enough regulation should be phased out. As of 25 July 2003, the implementation of the new EU directives will result in a regulatory set-up to ensure, in a flexible and suitable way, the competitive framework and consumer protection in the Danish telecommunications industry. This is to be achieved through very careful regulatory planning according to the actual market conditions.

Framework conditions for telecom services
New advanced telecommunication services - communication, information and entertainment services - are of increasing importance to the market. These services are essential in a competitive perspective and will, at the same time, contribute to improving the Danish knowledge system, e.g. by increasing mobility. Studies and analyses should ensure that telecommunications regulation contributes to creating the ideal framework for developing and spreading services.

The home computer scheme
This scheme, which became effective in January 2002, provides employees with the opportunity to tax deduct the amount paid to their employers for having a computer with accessories made available to them. To qualify for this deduction, the employer must pay a minimum of 25 per cent of the costs of the scheme. Thus, the home computer scheme provides a tax exemption for data communication paid for by the employer as long as the employee has access to the employer's network.

IT security
In August 2002, an IT skills centre was formed for the purpose of providing counselling and initiating information campaigns on IT security, setting standards, ensuring a governmental warning system as well as furthering education and research in the area of IT security.

The Council on IT Security was formed on 1 January 2003. The purpose of the council is to provide public authorities, the private sector and citizens with broad knowledge of IT security and to contribute to safe and confident IT usage in Denmark.

Digital signatures
We are currently working to establish a common national IT security infrastructure based on digital signature technology. Digital signatures will make it possible for the public sector to offer citizens far more advanced electronic services than those available today. Based on an EU tender, the Ministry of Science, Technology and Innovation will enter into a contract for the provision of digital signatures in 2003.

XML: common standards for the exchange of data
To ensure easy and inexpensive integration of public sector IT systems and of joint public and private IT systems a project has been initiated to standardise the documentation of public data with the use of XML (eXtensible Markup Language) communication technology. In addition, a database will be established where it will be possible to search for the information needed for simple integration of the IT systems. DKK 50 million has been appropriated to the project for the financial period 2002-2004.

Regional IT Drive - Jutland and Funen
The Regional IT Drive for the regions of Jutland and Funen is a new initiative designed to improve interaction between the business and industry community and knowledge institutions

in these areas. The purpose of the initiative is to make sure IT knowledge available in the knowledge environments of Jutland and Funen is utilised by companies to a greater extent – not only in the university towns, but throughout the Jutland and Funen regions. The Government, in collaboration with the parties that supported the UMTS political agreement, has appropriated DKK 175 million to the IT Drive in the financial period 2002-2005. These appropriations are supplemented by a corresponding amount from the counties, municipalities, universities and business and industry communities in the Jutland and Funen regions.

IT research initiative

The IT research initiative is to focus primarily on the development of new IT competencies in research, education and business and industry. Furthermore, the initiative is to ensure that companies and research institutions in future years can recruit and train young IT researchers to ensure continued growth in the IT industry in Denmark. In connection with the 2003 Budget, the Government and parties involved in the political accord have entered into an agreement regarding the implementation of the UMTS proceeds for the period 2003-2005. To this end, DKK 115 million has been appropriated to a national IT research initiative.

A sector in growth?

The Ministry of Science, Technology and Innovation in conjunction with the IT industry has initiated a study of the importance of the IT industry for Danish growth. The purpose of the project is to provide the IT industry and the Government with a common knowledge base founded on reliable documentation. The study should ensure that the political debate on the IT industry can be supported by fact rather than myth.

[1] Competency is defined as: "The ability to meet requirements of a high complexity. Competencies do not only incorporate knowledge and abilities, but also strategies and routines necessary to employ knowledge and abilities as well as qualified feelings and opinions along with an efficient self-control of these components. Competencies are aquired. To obtain competencies is considered a contineous life-long teaching process. (OECD, 2000:8)

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6.1 On the right path

Denmark is one of the most prosperous countries in the word. We have created a welfare society and our companies generally do well in international competition. However, there is no guarantee that this will prevail.

The Government's knowledge strategy has shown that we have the potential to continue to do well in the future knowledge-based society. But the strategy has also highlighted some areas where we are faced with some serious challenges.

In 2002, the Government took *the first step*. University, government research and research council system reforms in conjunction with efficient IT usage should contribute to realising the goal of strengthening the Danish knowledge system's position as one of the most efficient and competitive knowledge systems in the world.

Based on this, 2003 will be characterised by hard work to implement these reforms - and to convert new legislation and new appropriations into actual progress for knowledge workers, knowledge institutions and companies.

Better interaction and concrete collaboration between companies and knowledge institutions is a very important issue in the effort to meet these challenges.

6.2 The next steps

In addition to the task of realising these reforms, the Government will launch new initiatives, which can contribute to strengthening the Danish knowledge system - and the six action areas. This primarily involves the following major reforms and initiatives:

Reform of ordinary post compulsory education and higher preparatory examination (HF) programmes: With the upcoming post compulsory education reform, the Government wants to strengthen the actual academic competencies of young pupils, and hereby contribute to a larger percentage of them completing a course of higher education. Post compulsory education should provide academic and personal challenges for all pupils and should ensure that they get an all-around education, which prepares them for active participation in the knowledge society. The purpose of reforming the two-year HF programme is to ensure the study competency of the pupils and to provide a relevant foundation for choosing an education and profession. Academic proficiency should be broadly improved and it should make it possible for pupils to form their own profiles in their education with a view to choosing a course of higher education.

Reform of the Authorised Technological Service Institute (GTS institute) system: The purpose of this reform is to prepare the GTS system for the challenges of the knowledge society and to strengthen the GTS system's interaction with companies and the rest of the knowledge system regarding innovation and technology utilisation. Furthermore, the GTS institutes are to interact more closely with other research and knowledge institutions, also internationally. As part of this reform, a new model will be developed for the public financing of the GTS system, which will make technological service in Denmark more dynamic and flexible. This should be achieved by, among other things, making it possible for new players to participate in the development of technological services and to increase the competition for funds by emphasising project financing and tenders. The Government expects to initiate this reform in the beginning of 2004.

Action plan for entrepreneurs: In the beginning of 2003, the Government submitted its action plan for entrepreneurs. This action plan identifies entrepreneurship and risk acceptance, resourcefulness, administrative conditions, counselling and business services, financing and taxes as well as commercialisation of research results as vital elements in an efficient and goal-orientated enterprise-promotion policy. The action plan for entrepreneurs is the Government's vision for the specific political initiatives needed for more people to establish their own businesses and to help them achieve a period of growth as quickly as possible. The plan comprises a total of ten specific proposals which the Government intends to implement in the coming years. The action plan centres on the initiative targeting high technology and knowledge-based entrepreneurs.

The Preliminary Government Research Budget: A new overview - The Preliminary Government Research Budget - will annually provide a complete picture of all public appropriations for research, development and innovation in Denmark. This is intended to create greater transparency with regard to appropriations under the individual ministries as well as to provide a better foundation for decision-making with regard to political priorities.

The 2003 IT and Telecommunications Policy Action Plan: As described in the Government's 2002 IT and Telecommunications Policy Statement and Action Plan, the purpose of the Government's IT and telecommunications policy is to create growth, reform the public sector and qualify Danes for the future knowledge society. In 2003, the Government plans to launch a new IT and telecommunications policy action plan. In addition to updating the most important initiatives in the area, the action plan is also expected to focus on:

> *The potential for e-learning*: The Ministry plans to initiate a study to shed light on Denmark's potentials with regard to e-learning. The focus of the study will be on competency development in small and medium-sized enterprises and the public sector.

> *IT in central government*: This focuses on the areas where it is advantageous to view the central government as a unit in relation to IT usage. More specifically, work will be concentrated on IT architecture, common networks, benchmarking and a software strategy for central government. A report describing the complete project and the first concrete initiatives will be published in spring 2003.

> *Competition on the telecommunications market*: Generally, the area is dealt with through dialogue with the industry and consumer representatives, while information initiatives create greater transparency on the market. Furthermore, the competition on the market is also being monitored. By the end of spring 2003, the Danish National IT and Telecom Agency will conduct a study of potential barriers to an efficient telecommunications market in Denmark. This study will be conducted in close collaboration with players in the industry and will deal with the telecommunications industry on a wide scale.

The action plan for strengthening interaction between the business and industry community and knowledge institutions: In spring 2003, the Government will present an action plan for strengthening interaction between the business and industry community and knowledge institutions. The Government presents a number of specific initiatives focusing on interaction, including initiatives to strengthen the commercialisation of research results. The main goals of the action plan are:

> *More partnerships between the business and industry community and knowledge institutions*: The establishment of a network between companies and knowledge environments which can strengthen the dialogue and collaborative efforts between the two parties is a central aspect of the action plan. The Government wants to support the establishment of partnerships between the business and industry community and knowledge institutions to increase business and industry's incentives to invest in research and development. Furthermore, the Government wants to coordinate and focus public investments in innovation and strategic research to increase the chances for achieving synergies and critical mass in Danish research environments.

> *A flexible institutional framework for interaction*:
> Danish research institutions must have unrestricted and flexible opportunities to collaborate with business and industry. The Government wants to strengthen researcher mobility and collaboration between private and public-sector research with the use of more flexible types of employment. At the same time, the Government will support new ways to organise research which increase the opportunities for collaboration with business and industry and which ensure dynamic research environments. Furthermore, the Government wants to work towards setting forth goals and strategies for the development of, among others, knowledge exchange, technology transfer and interaction with the use of second-generation university performance agreements.

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- *A new structure for technology transfer*: A new policy on the commercialisation of research results will be a central initiative in the Government's action plan for strengthening interaction between the business and industry community and knowledge institutions. The Government will specifically focus on the opportunities for technology transfer and, in this context, lay down the framework for closer interaction between knowledge institutions, innovation incubators and science parks.

- *Increased freedom for public research commercial activities:* With the draft legislation on the new University Act, institutions will be more strictly required to promote the transfer of knowledge and technology to the business and industry community and society. In this context, the Government will also consider the need for increased freedom for institutional commercialisation efforts. This includes better opportunities for financial involvement in new companies, innovation incubators, science parks and other technology disseminating bodies. In this respect, the need for new legislation is being investigated.

- *Improved access to knowledge institutions*: It should be easier to gain access to research institutions and to enter into collaborative agreements with researchers and research environments. The Government seeks to create easier and more consistent communication flows from companies to relevant researchers and research environments at universities. The Government also wants to develop simple and clear collaboration models. Furthermore, the Government feels that there is a need to further the development of new and flexible continuing training for companies.

- *Strengthened collaboration with foreign knowledge institutions*: More Danish companies should interact with leading foreign knowledge sources. The Government intends to improve companies' opportunities for participating in EU research programmes. At the same time, it is the goal to strengthen the incentive for foreign knowledge institutions to take part in a number of research and innovation initiatives.

6.3 In the longer term

With this knowledge strategy the Government has presented a proposal for the way towards continued growth. However, an effort is still needed. The current reforms need to be further developed and specified. Achieving increased synergies between the various research and educational institutions, the technological services, companies and the IT and telecommunications initiative is an on-going process.

In order to elaborate our knowledge system, we will need to strengthen our recruitment of knowledge workers for knowledge institutions, companies and society in general. At the same time, we need to find new ways to promote investments in new knowledge - especially in the business and industry community.

One key aspect of the future renewal of the Danish knowledge system will be gearing the effort more towards internationalisation in research, education, innovation and IT. A coherent effort in this area should pave the way for the increased exchange of knowledge workers and students, for new alliances between Danish and foreign knowledge institutions and for the increased internationalisation of Danish research and innovation programmes. In this context, IT and telecommunications will be a useful tool to remove traditional distinctions.

Along with the other initiatives, such an effort would make Danish knowledge institutions and companies more competitive and attractive in the future global knowledge market. Those countries, which are quick to open up and internationalise their knowledge systems, will stand strong in the long run.

Technology develops very rapidly - and sometimes it has far-reaching perspectives - causing many citizens to become uncertain. We need to maintain our focus on an ethical approach to technological development with a high degree of openness towards e.g. biotechnology and medical research. In addition, and we need to work on increasing the general public's interest in science and new technology.

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In several of these areas, we need new knowledge to further develop our knowledge system - i.e. better statistics and a better understanding of the context of knowledge production, including more knowledge regarding the technologies of the future and its consequences for society.

Many players are involved in knowledge production and utilisation in Denmark. And the more these players collaborate and move in the same direction, the more efficiently we can produce and utilise knowledge.

The challenges facing the Danish knowledge system cannot be dealt with solely by a public-sector effort. It is a joint public/private project. Through attractive framework conditions for knowledge institutions and the business and industry community, we must create a healthy climate for investments in our common future - knowledge in growth.

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Part 2: Four driving forces in the Danish knowledge society: documentation 2003

Contributions from researchers >

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Chapter 1: Introduction and summary >

Today knowledge is one of the most crucial production factors in most production processes, in both the production of goods and the production of services. Thus, Denmark's ability to produce knowledge and put knowledge to use in these production processes is one of the essential preconditions for retaining its capacity to thrive in tough international competition, to continue to create economic growth and thereby ensure a high standard of living for its citizens.

But where and how is new knowledge created and disseminated in Danish society, and how do we fare in international competition, in terms of creating new knowledge and putting it to use?

The purpose of this section, "Four driving forces in the Danish knowledge society - documentation 2003", is to illuminate some of the central driving forces in Denmark's development as a knowledge society: research and development work (R&D), education, innovation, and IT and telecommunications. There are other driving forces, but this report focuses on these main forces.

In chapter 2 we examine the views of the experts on what creates growth in the knowledge society. Theoretical economic literature describes the significance of the four driving forces for growth in society. The literature is based on both domestic and international research projects.

The countries that invest in the four driving forces have high economic growth. This conclusion is based on a review of economic studies. This material suggests that almost half of the economic growth in the industrialised countries since 1950 derives from technological progress combined with investments in research, innovation and education.

From this theoretical starting point, we call attention to the fact that when business and industry invest in **research and innovation**, it obtains a return on investment of 20-50 per cent, and for society as a whole the return is even higher - up to twice as much. The innovative networks that form around R&D and education at public research institutions are essential to the ability of companies to convert knowledge into innovation and growth. In large innovative firms, up to 20 per cent of their innovations are based on the results of publicly financed research. We estimate the indirect effect of education, informal networks and entrepreneurs to be even higher.

The studies also stress the necessity of a division of labour in research and innovation systems, combined with an efficient, dynamic interaction between the players in this division of labour. Thus, the studies indicate that if R&D investment is left exclusively to business and industry, it will result in under-investment, as business and industry often are reluctant to invest in basic research - knowledge with a uncertainty about future returns that is too great or or knowledge with a return that lie far in the future.

Another important driving force for growth that the studies identify is **education**. Sustained economic growth depends on a constant expansion of the human capital that exists in society. It is estimated that an improvement of the population's average educational level by one year increases productivity by up to 10 per cent.

In addition, developments in **IT and telecommunications** are considered to have been one of the most crucial factors in the economic growth of the United States in the past 10-15 years. One reason for this is that IT improves the opportunities to quickly collect and disseminate the knowledge that is obtained through the research, education and innovation processes. IT is integrated in many products and work processes and therefore, in itself, constitutes a fundamental condition for the further development of the knowledge society in Denmark.

These four driving forces are critical conditions for high technology and knowledge-based production in Denmark. The utilisation of these driving forces helps create higher productivity and growth.

Chapter 3 shows, by means of statistical data and key figures, how R&D, university education, innovation and the spread of IT each represent important factors in growth and shows how these four driving forces contribute to the development of Denmark as a knowledge society. At the same time , they are prerequisites for one another, and together they ensure a forward-looking development in all segments of society and its institutions.

Research and development

Total Danish investments in R&D in 2001 were DKK 32.2 billion. The public sector accounted for one-third of these investments. Consequently, Denmark's R&D work accounts for approximately 2.4 per cent of the gross domestic product (GDP), which is above the EU average, but below the level of the leading R&D countries.

In Denmark, business and industry are dominated by small and medium-sized enterprises that do not have enough volume to undertake substantial investments in research independently. In this way, 80 per cent of the investments in research made by companies that conduct R&D go to their own development work, 15 per cent go to applied research and 5 per cent go to basic research. In the public sector's R&D work, the ratio is the opposite, with basic research accounting for 49 per cent of research investment and applied research accounting for 38 per cent.

The figures for scholarly publications per million inhabitants is one of the indicators most often used internationally as a direct measure of the result of investment in research. Overall, Denmark ranked third among the world's leading countries in 1999 and 2001 by this standard. Furthermore, Denmark's relative research quality stands at the top in both quantity (number of publications) and quality (how often the publications are cited by other researchers) per Danish krone invested in research.

University education

In 2001, approximately DKK 10 billion was invested in universities, including 3 billion for ordinary education and 3.3 billion for basic research. Generally, the educational level in Denmark has improved significantly in the past 20 years. More than half of a given generation now initiate a short, medium-cycle or higher educational programme, compared with less than one-third in 1980. Approximately 18 per cent begin a university education. In 2000 there were a total of 100,000 students enrolled at universities.

The Universities admit about 18,000 students each year, with most (70 per cent) studying subjects in the social sciences and the humanities. In 2000, there were 8,592 new recipients of Candidatus degrees (Master degrees), and the number of graduates has risen steadily since 1980. Of the adult population, 27 per cent of the adult population has completed a course of higher education, compared with the average for the OECD of 23 per cent. However, short and medium-cycle higher educational programmes are included in this figure. A level of 18 per cent that initiate a university education is slightly below the OECD average.

At the same time, the number of Ph.D. candidates, that is, the number of Master graduates who continue in a Ph.D. programme, has more than doubled in the past 10 years, although it has stabilised at about 1,100 in recent years.

Innovation and networking

The number of new companies is crucial for dynamism and innovation in an industry. In 2000, 18,624 new companies were started, in comparison with 14,261 in 1995. In the period 1995-2000, nearly 100,000 companies were founded. Approximately 30 per cent of these new companies were established in the knowledge-based service and high technology industries. With a survival rate of 46 per cent over four years, these companies are also the most durable. In addition, new companies in knowledge-based services and high technology have the highest growth in turnover.

Danish companies are innovative. 41 per cent of Danish companies with more than 10 employees innovated in the period 1998-2000. In 2000, investments in innovation amounted to 7 per cent of the companies' turnover. 15 per cent of the innovative companies' turnover derive from products that are so new that they also are new for these companies' markets.

Collaboration has great significance for companies' innovative efforts. About 40 per cent of Danish companies with more than 10 employees that have been innovative also collaborated with others on innovation in the period 1998-2000. Of the collaborations, 71 per cent of the collaboration took place with other Danish companies. 40 per cent took place with private Danish knowledge institutions, consultancies, private R&D institutes and technology service institutions. 32 per cent took place with public research institutions in Denmark. As far as collaboration on research is concerned, 54 per cent of Danish companies that conduct R&D activities have collaborated with others. Of these

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collaborations, 50 per cent took place with other companies, while 25 per cent took place with public knowledge institutions.

The export of high technology goods may give an indication of the knowledge intensity in a country's goods and the result of the country's efforts to innovate. With a 20 per cent share of exports, Denmark's high technology goods industry is above average compared with a number of OECD countries. However, in countries such as Ireland, the Netherlands, the United Kingdom and the USA, high technology goods account for 30 to 45 per cent of exports.

Patents are another important indicator of innovation activity. On the basis of the European patents per 1 million inhabitants, Denmark, in 1999, was below the countries which weusually compare ourself with, such as Sweden and Finland. The situation is the same with regard to American patents.

IT and telecommunications

Nationwide, inexpensive Internet access is an important condition in enabling everyone in the knowledge society to use the opportunities presented by information technology. Denmark is one of the world's leading countries with respect to penetration of fast access to the Internet. Almost 7 per cent of the population has a high-speed Internet connection. Since the liberalisation of the telecommunications industry in 1996, prices of IT and telecom services have fallen, and hereby the barrier to IT-usage has been reduced year by year. In an international context, Denmark has some of the lowest prices for ADSL services in Europe.

65 per cent of Danish households have access to the Internet at home, and 54 per cent use the Internet at least once a week. The spread of IT-usage by companies is also on the rise, but here it is the integration of various electronic business systems rather than simply having a website that is the centre of attention. IT utilised by business promotes e-commerce and improvements in productivity. Another factor that improves productivity and services is the use of the Internet by private citizens and companies to come into contact with public authorities. This form of Internet usage is also increasing. More than half of the companies with Internet access use the Internet to come into contact with public authorities.

In an international context, a relatively high percentage of Danish companies uses the Internet to submit orders. Overall, this applies to almost half of Danish companies with more than 10 employees.

The public sector's use of IT is a central precondition for the entire society to benefit from technological developments, and it also sets an example for IT use in business and industry. It has now been documented that public authorities that have restructured their work procedures and the delegation of competencies in connection with digitalisation projects, liberate a portion of their resources more often than those that have not.

In chapter 4, we focus on the intensity of knowledge and research in Danish business and industry.

First, we present a classification of industries that divides business and industry into knowledge-based service companies, high technology companies and medium-high technology companies and makes it possible to compare the Danish business community with those of the other OECD countries. The OECD has classified industries according to the intensity of their research and development activities. The study shows that the value added in Denmark's high technology and medium-high technology companies is above the average for the EU and the OECD, but below the value added value added in both Sweden and Finland.

From a Danish perspective, there are several inappropriate factors in the OECD's classification. First, such a general categorisation means that particularly prominent industries in Danish business and industry become lost in the volume. This suggests that the OECD approach must be considered too general and broad in relation to the special characteristics that apply to Danish companies; for example, the R&D effort in Danish business and industry is concentrated in very few companies and sectors which, however, are dispersed across several of the general OECD categories.

The companies that conduct intensive R&D are placed in several different sectors in Denmark, in both the industri and knowledge services.

The 50 largest R&D companies account for approximately half of the total R&D activities in business and industry. These companies employ 77,000 people, equivalent to an employment of 1,500 people per company. The R&D expenditure per full-time employee is DKK 95,000, and the companies' earnings are twice as high as the average in the rest of the business community.

To obtain a more precise idea of the significance of knowledge-intensive business in Denmark, we must consider individual companies tomore closely examine the development of companies that make a major effort in R&D.

Knowledge-intensive companies are defined as companies with a minimum of 5 employees with a university degree, either Master og Ph.D.(knowledge workers), who also represent at least 10 per cent of the company's employees.

The analysis of knowledge-based companies shows that there is a significant concentration of these companies in Danish business and industry. There are just over 1,800 knowledge-intensive companies in Denmark, equal to 3 per cent of all companies with 5 or more employees in the private sector. However, these 3 per cent account for 63 per cent of all knowledge workers.

The study also shows that the number of knowledge-intensive companies increased sharply - by 40 per cent - from 1995 to 2000. More than 1,000 new knowledge-intensive companies have been established during this period.

At the end of the chapter, we investigate three industries that use R&D, employees with university-education, innovation and IT intensively, and look at the industries' financial strength.

By choosing three areas in business and industry that are characterised by a high degree of knowledge-intensive work procedures, we can explore the extent to which these three industries convert the four driving forces into economic growth. The concentration of knowledge and development in the IT industry, the media and communications industry and the pharmaceuticals industry shows that there are grounds for examining these three areas further. These three focus areas together employ one-third of the Danish knowledge workers, and there was strong growth in the number of knowledge-intensive companies from 1995 to 2000 - as high as 86 per cent for IT companies. In addition, these areas account for half of all the R&D activity in Danish business and industry.

The focus areas as a whole comprise approximately 550 knowledge-intensive companies, or one-third of all Danish knowledge-intensive companies.

The level of value added and/or salaries in the three focus areas clearly standsabove the level in the rest of the private sector. Earnings in the pharmaceuticals industry are twice as high as earnings in the remainder of the business community. In addition, the IT and pharmaceuticals industries also have a considerably higher percentage of R&D investments, of employees who are university-educated or hold Ph.D.s and of employees with degrees in the natural sciences or technical fields.

In a series of boxes, we present the actual work of a number of Danish researchers in analysing the knowledge society. The boxes also concern the challenges and opportunities that all companies and society must continue to work at addressing and exploiting. Thus, the theoretical description and the Danish researchers' contributions lay the foundation for the subsequent chapters, in which the four driving forces are illuminated from various angles through statistical key figures.

The results of the researchers' studies are presented in separate boxes to underscore that the researchers invited were not involved in the preparation of the statistical part of this report. Consequently, the selected researchers cannot be held responsible for the content or the form of the report.

> Up to 50 per cent of economic growth in the industrialised countries since 1950 is due to technological progress.

> If R&D investment is left exclusively to the business community, the level of investment will be lower than the level required for optimal economic development. This is particularly significant for a country such as Denmark whose private sector is dominated by small and medium-sized enterprises.

> For both companies and countries, relying on the R&D activities of others involves large business risk.

> Education is so great a driving force for growth that an improvement of the population's average educational level by one year increases productivity by up to 10 per cent.

> IT has contributed more than 20 per cent of the productivity growth in the USA in recent years.

> The innovative networks around research and education at public research institutions are essential to the ability of companies to convert knowledge into innovation and growth.

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2.1 The driving forces behind growth in the knowledge society >

Denmark and most other OECD countries stand on the threshold of the knowledge society. This means that, in our part of the world, knowledge is becoming one of the most important value-adding factors. In any case that is the economic justification for using the designation "knowledge society".[1] At the same time, societies are woven increasingly closer together. Globalisation means that we can produce knowledge in Denmark and convert it into production in e.g. India. Thus, in some ways, the entire global economy is becoming more imbued with knowledge work.

Knowledge is a complex issue. To use a metaphor from chemistry, knowledge is transient material that does not attain value until it is brought into contact with other elements. For example, knowledge acquires value when it is converted into a patent that someone pays for and uses in order to make a product. That completes the value chain. However, only a small portion of the knowledge that is produced at knowledge institutions and companies is converted into patents and products in this way.

In other cases, knowledge is transferred through teaching. Graduates bring knowledge with them when they begin a new job. This knowledge is actually a precondition for them to hold a job and create value. Knowledge is also the way in which we organise our companies and the way we structure our society and our lives.

Research has traditionally been a central source of new knowledge. But knowledge is created in other ways as well: when people exchange experiences with one another, when companies learn from their customers,[2] when colleagues learn from one another, and when we all think about what we are doing in our jobs.[3]

Often people do not know how much knowledge they actually have.

Economists call the knowledge that we are unaware of "tacit knowledge".[4] Tacit knowledge proves to have great significance, for example, when production must be moved from Denmark to China. The Chinese must of course have the necessary software, machinery, and so on. But it often turns out that, when transferring technology, it is necessary to give guidance in a number of other areas, such as how one makes auxiliary tools and what one does in unforeseen situations. This type of knowledge will often be tacit, as it is found among the specific persons who previously performed these functions.

In other words, there are many sources of knowledge, and knowledge can assume many forms. Knowledge is turned into value and growth in many ways. There are therefore also many players in the total knowledge system who bring, transfer and use knowledge to create value.

Tacit knowledge and codified knowledge

There are two general types of knowledge: Tacit knowledge and codified knowledge

Codified knowledge

Codified knowledge is knowledge that can be conveyed in manuals, articles, programs and the like.

Tacit knowledge:

Tacit knowledge is knowledge that cannot be written down or represented graphically. Tacit knowledge consists of skills, experience and intuition.

Tacit knowledge is typically embedded in routines or an organisation's culture. This type of knowledge is difficult to convey because it is borne by employees. Tacit knowledge can therefore be transferred to some extent upon a job change, which usually has a certain geographical limitation. New technology such as IT can advance the process where knowledge is stored, conveyed and communicated more quickly than previously. It is therefore possible that tacit knowledge will become less significant over time.

Source: Oxford Research A/S on the basis of research by Polanyi (1966) and others.

The knowledge society is both an information society and a learning society >

Name: Bengt-Åke Lundvall
Position: Professor, Institute for Business Studies, Aalborg University

Since Denmark is to have a national knowledge strategy, there are good reasons to reflect upon what a knowledge society is. For it is not always clear what is meant when we say "we live in a knowledge society".

Knowledge is as old as mankind. In all historical societies, economic and social processes have been based on knowledge.

In primitive civilisations, knowledge was anchored in traditions that were transferred between generations by oral tradition and common experience. Later came the general spread of common written languages, schools and universities that enabled knowledge to be disseminated in a more systematic way.

One could therefore be tempted to see the knowledge society as a society in which these institutions, and information technology especially, play a significant role. According to this perspective, the degree of formalisation of the knowledge used should determine how far the knowledge society has come in its development.

One can also use quantitative indicators to mark the transition to a knowledge society.

A rising level of education and increasing investment in research and development can thus be seen as an expression of an increasing use of knowledge in economic and social processes. One can also examine how the division of labour is developing in society and especially how large a portion of the total labour force that is employed in the processing of knowledge.

All of these indicators point in the same direction - more and more knowledge is used to produce end-products and services, whose value is increasingly determined by the knowledge they contain.

"Knowledge about" - or "know-how"

It is crucial to differentiate between knowledge as information about the world and knowledge as an ability to change the world.

"Knowledge about": is what one can generally acquire in school and from books. Attaining "knowledge of how" one does something usually requires practice as well as the training of less experienced employees by more experienced ones.

The knowledge society is characterised by a sharp growth in the volume of "knowledge about" stored in books and electronic media. On the other hand, the ability to find, retrieve and use this information is more limited. One factor that makes a crucial difference in global competition between regions and companies is "know-how" seen in relation to how one further develops, disseminates and uses "knowledge about".

The learning society

Perhaps the expression "the learning society" is the most accurate way of describing the present form of society. One implication of this term is that especially the pace of the process of change in society and the economy has changed. Consequently, how one learns - the ability to learn - will determine who thrives best in competition over the longer term. The term also encompasses the fact that, in the present stage of development, knowledge and competency quickly become obsolete. New problems arise, and in order to address them, one must be able to forget the old ways of thinking and embrace new paradigms and skills.

From this perspective, it is also clear that there is a need for radically new ways of thinking regarding the purpose of education (in which one must learn to learn, and learn throughout one's life), the labour market (where the criterion of a well-functioning labour market is that one constantly ensures a renewal of competencies in both individuals and organisations) and the work organisation (where it is

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important that the form of the organisation supports learning processes for the employees). New types of inequality that reflect unequal abilities to learn or unequal access to learning require a new type of distribution and social policy.

The great challenge

From this perspective, universities and research laboratories continue to serve as important sources of knowledge, but they are far from the only ones. In the business community, it is not only research-based pharmaceutical and electronics companies that need to draw upon the various sources of knowledge. All activities in all parts of society are subject to a pressure to change that sets demands for new competencies.

The knowledge society is a society in which formal knowledge has much greater importance than the skills and competencies that are developed by individuals and organisations. But it is also a society in which the renewal of skills is crucial in enabling the growing volume of information and formal knowledge to be applied.

The great challenge lies in finding new ways of combining the use of information systems with a continual renewal and development of the human resources in society as a whole. This must be the overall purpose of a national knowledge strategy.

You can read more here:

www.business.auc.dk/ike/members/bal.html

Lundvall, B.-Å. (2002). *Growth, Innovation and Social Cohesion: the Danish model.* London, Elgar.

Lundvall, B.-Å. and Johnson, B. (1994). "The Learning Economy", *Journal of Industry Studies*, Vol.1, No. 2, pp. 23-42.

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Can we achieve higher growth in society by investing more in the production of knowledge? If so, where and how should we invest?

This chapter summarizes a selection of central studies that attempt to answer these questions. The survey is not specific to Denmark, but applies generally to knowledge societies such as Denmark.

As an introduction, we present the theoretical explanations of the relation between knowledge and growth offered by economic research. Next, we focus on the four driving forces behind growth in a knowledge society.

- Research and development work
- Education
- The interaction between universities and the business community in innovative networks
- IT and telecommunications

There may be other explanations and driving forces, but in this report we focus on these four, which according to the experts also are essential in increasing productivity and growth in a knowledge society.

The economic research relies upon a number of conditions that are never completely fulfilled in reality. The results of the research are therefore rarely unequivocal. The assumptions of the studies are discussed on an ongoing basis, and the general conclusions are presented in the chapter.

There are several schools and opinions in the economic research, and there is much debate on the relevance and usefulness of the results of the various schools. In this chapter we seek to summarize results of the various schools that naturallyare open to debate, but the purpose of the chapter is to review the results regardless of schools and opinions. For a more detailed discussion of the assumptions and other issues, see the original sources cited in the text or the footnotes.

The results presented in this chapter must be seen as the best explanation from the experts of what creates growth in a knowledge society.

The conclusions do not apply to Danish conditions in all cases, but they might inspire a general discussion of where an how it would be desirable to invest in knowledge with an eye to sustaining continuous growth in Denmark.

The chapter and the review of the existing research was prepared by the Ministry of Science, Technology and Innovation partly on the basis of research conducted by Oxford Research.

[1] In recent years the OECD has treated the transformation of the industrial society into a society based more on knowledge in a number of publications. See for example OECD (2000b) and OECD (1999a).

Lundvall, B.-Å., “Product innovation and user-producer interaction” (1985) and Madsen, P.T., “Den samarbejdende virksomhed” (The collaborative company), DISKO report (1998).

[3] Arrow, K., “The economic implications of learning-by-doing”, 1962.

[4] Polanyi, M., “The tacit dimension”, 1966.

2.2 The theoretical relationship between knowledge and growth >

A country must invest in knowledge because the development and use of knowledge in organisations, services and goods are two of the fundamental preconditions for growth in a knowledge society.[1]

Private companies invest in knowledge to increase profitability and upon the expectation that in the longer term this will increase earnings.

The public sector invests in knowledge because the economic return for society on the investment in knowledge in many cases is higher than the return for private companies and this is not obtained through private investment alone. For example, knowledge developed in the biotechnology industry is used in the agricultural sector without diminishing the value of the knowledge in the biotech industry. The public sector must therefore invest in certain forms of knowledge, for example basic research, education or IT, in order to ensure the highest possible returns for society and the best possible conditions for growth in a knowledge society.

Production produces value in the economy. Historically, agricultural and industrial production produced goods that could be sold for money in a market. Today goods are more than physical objects. We also trade in services such as consulting and entertainment.

An important question for society is, what aspects of production create value? Historically, the answer has been the interaction among the three primary factors in production:

> Land - particularly in agricultural production
> Capital - in the form of machinery, raw and subsidiary materials, buildings and so on.
> Labour - employees, management and others.

Prices can be attached to these production factors: the price of using land, the interest on borrowed capital and the pay for employees and managers. The economy can therefore show the value of what goes into production and compare it with the value of what comes out. Productivity is the measure of how efficiently the individual production factors are employeed.

Knowledge enters the equation by increasing the output per unit of labour and capital. The reasons are that knowledge in the form of education produces a more efficient workforce and that technological progress produces more efficient machinery and work processes. The focus is therefore often on productivity growth rather than simple growth in production.

Productivity as a measure of the effect of R&D

Productivity is defined as the production that is achieved by a given combination of these production factors:

$$\textit{Productivity} = \frac{\textit{output}}{\textit{input}}$$

The purpose of research, education and innovation in this context is to create greater knowledge per unit of labour as well as technological progress that makes it possible to produce more or better products with the same or a smaller consumption of labour and capital – that is, higher productivity.

There is a long empirical tradition of analysing the development of productivity on the basis of the specific contributions of labour and capital. Empirical studies showed as early as the post-war period that a smaller and smaller portion of productivity growth was owing to increased inputs of the traditional production factors. The (growing) portion of productivity that could not be explained by growth in labour and capital was called total factor productivity (TFP). TFP is therefore a kind of residual factor that covers the productivity effect owing partly to improvements in labour skills and speed and improvements in the output and efficiency of machinery. In other words, it is the effect of developing more knowledge and technology.

Source: Oxford Research A/S, 2002.

Who should invest in knowledge?

The question of why one should invest in knowledge is difficult to distinguish from the question of who should invest. The general answer is that both the public and private sectors should invest in knowledge. The general argument that the business community should invest in knowledge is simple: knowledge increases the yield of production. It is less obvious why the public sector should invest in knowledge. Nevertheless, there are five important arguments that are confirmed by a number of studies.

> Investments in knowledge, no matter who undertakes them, benefit society at least as much as they benefit private sector production (see note 2). Unlike most other resources, knowledge is not something that is diminished when one uses it; on the contrary, knowledge can easily be shared.[3] Companies can copy one another's inventions; people switch from one workplace to another and take their knowledge with them. We therefore distinguish between the return for an individual company and the (total) return for society. The return for an individual

company is usually measured as the portion of the growth of production that can be attributed to the company's own R&D investment. The return to society can be identified as the growth in production for the entire economy that can be attributed to specific R&D investments. The return for society must therefore be determined by an aggregate analysis of the effect of R&D investment on production, either for an entire industry or for the entire economy. Since the return for society is larger than the return for business and industry, too little might be invested if investments in knowledge are made only by business and industry.

- Knowledge is a risky investment where the return may not manifest itself in the shorter term. Therefore, e.g. small companies, might often be reluctant to undertake such investments. This argument is especially true of investments in basic research.[4]

- Basic research can be difficult to patent. This reinforces the argument that companies are reluctant to invest in basic research. Since basic research is one of the conditions for applied research, the total research effort will be limited if the public sector does not contribute to the investments.

- Knowledge is converted into value in many ways, some of which are very indirect. This is true, for instance for knowledge about how society is structured, what creates trust and what reduces corruption. Such knowledge has no direct significance for value added, but indirectly it has great significance for the total creation of value. If the public sector does not invest in this form of knowledge, there will not be an adequate investment in it.

- Some forms of value cannot be calculated in terms of money. This is the case, for example, with quality of life, which might become better according to how much knowledge we have about health, history, culture and so on. If the public sector does not invest in this form of knowledge, we might have a lower quality of life, although we might perhaps have the same growth and productivity.

[1] OECD (2001b).

[2] Both Griliches (1995) and Cameron (1998) present an overview of a number of studies that find that the social return is greater than the economic return to business and industry.

[3] Knowledge has the character of a "collective good", which is the economic designation for a good or a product that does not have profit-creating properties to such a degree that private companies will choose to produce it to the extent that will be optimal for society. The reason is, first, that knowledge is a good that does not become smaller when one uses it (a "non-rival good"). Second, knowledge as an investment is difficult to protect as an asset from which others are excluded from having a part (a "non-exclusive good"). Although there is the possibility of obtaining patents, an amount of new knowledge usually becomes accessible at the same time that the product comes onto the market, apart from the fact that patents have time limits.

[4] Salter and Martin (1999) refer to a number of studies that indicate that companies usually invest more in applied research. That investment in R&D is made mainly by large companies is also confirmed by a number of empirical studies, including a Danish study by Dilling-Hansen et al. (1999b).

2.3 Research and development work

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Research shows that up to 50 per cent of economic growth in the large industrialised countries since 1950 is due to technological progress.[1] Generally, R&D in business and industry produces a larger return than public-sector R&D.[2] The dissemination of knowledge results in a significantly larger overall return for society as a whole than the return obtained by an individual company.

Public and private R&D investments
Generally, public and private R&D investments are thought to be complementary, so public R&D stimulates and supplements R&D in business and industry.

A number of studies have found a positive correlation between growth and R&D investment, innovation and technological progress.

The correlation is not straightforward. The processes involved are complex, dynamic and sometimes even arbitrary. A study by Sakurai et al. from 1996, however, confirms the correlation between large investments in R&D and high growth in total factor productivity (TFP).

Another important point from the studies is that the effect of R&D investment and technological progress on economic growth varies greatly from country to country. The explanation might be that the ability to exploit technological progress differs from one country to another, and this ability is closely related to the countries' technological and research foundations (Romer 1990).

It is difficult to transfer empirical studies of return rates from one country to another. This should be taken into consideration when one examines the results shown below, which concern either other countries besides Denmark or many countries taken together. From a Danish perspective, the most useful results come from countries that generally have the same technological level and are similar in size to Denmark.

The return on public investment in R&D
Private companies invest less in R&D than the optimal level for society as a whole.[4] There is therefore a need for public investment. This makes it crucial to look at the effects of public R&D and private R&D - including any effects of their interaction. A number of studies find that public investment in R&D also indirectly influences the extent of investment in business and industry (Smith 2001).

Several studies therefore seek to determine whether public R&D investment stimulates the level of the investment in business and industry in a positive or negative direction.[5] If publicly financed R&D either simply supplements private R&D or has a positive effect in stimulating private R&D, then there is a complementary effect. On the other hand, there is a substitutive effect if public R&D has a negative influence on the extent of private R&D by displacing investments that would otherwise have been made by private companies.[6]

For 16 OECD countries (including Denmark), the OECD finds that an increase in public investment in R&D of 1 per cent raises productivity in the total economy by 0.17 per cent (OECD 2001b). This effect appears to be greatest in countries where the universities' share of public investment funds is large compared to that of government research laboratories.

There is a certain lag in time before the measurable effects of public R&D investment appear. The return does not manifest itself until the research has led to new products or improvements in processes. Several studies suggest that the productivity effects of public investment in R&D take place with a delay of up to 20 years.[7] This is consistent with the fact that the public sector usually conducts a larger share of basic research, while the business community focuses more on applied research.[8]

Public investment in R&D creates growth in society especially through a positive effect on the business community. Studies show that R&D at public research institutions is the most important external source of companies' innovative activities and that this is especially pronounced at high technology companies.[9] In this regard, several studies confirm that companies with higher internal R&D investment can more easily exploit the results of publicly financed research.[10]

The return on private investment in R&D
The social return on privately financed R&D is greater than the return on publicly financed R&D

(Salter and Martin 1999). The explanation is that private companies choose to use their resources on R&D projects that are the least risky and the most practical – and therefore in the shorter term are presumably the most profitable and most likely to produce returns most quickly.

The return for society on private R&D investment appears to be at least twice as large as the individual companies' direct return (Griliches 1995). Studies estimate that the direct return obtained by individual companies is usually 10-50 per cent of the investment, while the total social return is usually 20-160 per cent.[11]

Geographical aspects of investments in knowledge

In an increasingly globalised economy, the return on investment in a knowledge society is not limited to one region or country. The return will also benefit the surrounding countries and regions. Studies of R&D investment estimate that about 25 per cent of the return on R&D in a G7 country will accrue to the country's trading partners.[12] However, it is still important for the individual countries to invest in R&D. First, because many studies indicate that innovative activities are often geographically anchored, so that, for example, companies near a public research institution obtain greater benefits than those farther away. Second, because it is necessary to have adequate "social capability" to take advantage of other countries' advances (see the box below).

Social capability

Social capability is a country's ability to import and initiate technological and organisational development. Social capability involves the educational level as well as political, industrial, financial and trade institutions. Fagerberg (1994) concludes that a combination of imitation and independent innovation is necessary for obtaining the maximum benefit from other countries' technological advances. Investments in new systems and copying others' progress is not enough; countries must also undertake their own technological research activities. The same fundamental relations apply at the industry level. Companies (countries) that conduct research themselves attain a greater ability to exploit other companies' (countries') research.

Geographical and technological proximity

The location of public research institutions can have great significance in stimulating research and innovation in private companies. The exchange of knowledge workers, personal contacts, networking and the like depend to a certain extent on geographical proximity.

Several studies indicate a correlation between the geographical proximity of organisations with R&D activities and the positive effects of the research. The same applies for private companies located close to one another.[13]

The distinction between direct returns for a company and the return to society on knowledge investments is of great significance. If geography plays a role in the dimension of positive effects, the following questions become central:

> What factors can promote positive effects?

> Where are the geographical effects greatest?

> Are there, for example, substantial positive effects across various industries, or are they primarily within an individual industry and between companies and/or research institutions?

These are among the conclusions reached by the studies:

> Knowledge production and innovative activities tend to gather together geographically. This is owing to access to tacit knowledge, which cannot be transferred over long distances (Arundel and Geuna 2001).

> There are large positive effects for companies that are located near public research institutions. The studies of the correlation between patents and research articles document that the patents refer predominately to articles from local research institutions (Salter and Martin 1999 and Cameron 1998[14]).

> Public research institutions are the most important source of knowledge for companies, and companies' geographical proximity is most important in relation to public research institutions (Arundel and Geuna 2001[15]).

Jaffe (1989) also finds weak signs of the effect of geographical proximity - as well as the interesting phenomenon that the effects are most clear in specific research areas.[16] This suggests that the positive effects are limited to narrower fields rather than general industries. Orlando (2000) also finds that the positive effects depend to a great degree on

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a combination of geographical and technological proximity. Technological proximity refers to the degree to which companies' research takes place in the same or related technological fields. Orlando also concludes that the technological distance between companies plays the biggest role. In the case of a small technological distance, the geographical distance between companies and research institutions in the same narrow technological field will therefore not limit the positive effects significantly.[17]

Technological proximity is thus a factor that affects the benefit to companies of investments made in research by the surrounding world. But the extent of a company's own R&D is just as significant. Several studies indicate that companies can increase their ability to exploit or absorb the results of others' research by conducting research themselves. This means that geographical proximity to research institutions and other companies has the greatest significance for companies that invest in R&D themselves.

American and European studies collectively suggest that the geographical proximity of knowledge institutions and companies is significant. But as in many other areas, this cannot be assumed to apply directly in all countries.[18]A particular characteristic of Denmark is that geographical distances are never great. Nor does business culture differ from one end of the country to the other to the same degree that it does, for example, in northern and southern Italy. This suggests that geographical distance is less significant in Denmark.

Nevertheless, there are many examples of Danish companies that have placed themselves in a local "cluster" of public research institutions precisely in order to achieve collaboration and indirect positive effects.[19] This is the case primarily in high technology fields, including the so-called ICT (information and communications technology) cluster in northern Jutland and the concentration of biotechnology and pharmaceutical companies in the Copenhagen-Øresund region (OECD 1999c). It is on this background that the reason the Disko project report No. 9 (1999) concludes that the regional interaction between companies and research institutions is attaining increasing significance.

The return on investment crosses borders

Geographical proximity is not decisive for the positive effects of R&D investment. Several studies confirm that the wider social effects of investment in R&D also cross national borders.

This takes place through various channels. These are two effects mentioned by Cincera and Pottelsberghe (2001):

> *Transaction-based* effects. These take place when a company in one country purchases production factors (such as technology or machines), semi-finished goods or patents from a company in another country.

> *Knowledge-based* effects. These depend on the technological distance between the two companies, and they take place indirectly, possibly as a side effect of the economic transactions mentioned above.

Cameron (1998) refers to a central study by Coe and Helpman for the G7 countries. The study indicates large positive effects of international investment in R&D. About 25 per cent of the total return on an investment in R&D in a single G7 country will accrue to its trading partners. Such a specific estimate must be evaluated cautiously, however, as there is particularly great uncertainty in the measurements of the international return on investment in R&D.[20]

Cameron's overview-study also recapitulates the conclusion that benefits from foreign R&D are obtained primarily through personal contacts and networking, which are often established with trading partners. Cameron mentions foreign direct investment as an important channel for the positive effects of investment in knowledge for the recipient country. The studies also show that small, open economies obtain greater returns on the R&D investments of their trading partners, than large countries do.

Other studies examine the extent of international effects. These studies show that certain factors play a large role in a country's ability to exploit international R&D investment. [21] The studies suggest that countries that lag behind the general economic growth of other countries only can achieve high productivity growth if they have sufficient "social capability" (see the fact box earlier in this chapter) to exploit the progress made by other countries.[22]

Studies of the ownership of innovative companies indicate that companies with operations in several countries obtain a greater return on their research. This shows that large positive effects can be obtained from other countries' research if a company has an especially close relation with the countries. If a company has a subsidiary in a country, it will be easier, other things being equal, for it to absorb the results of the research and the new technological progress that are created in the country. On the basis of Danish company data Dilling-Hansen et al. (1999b) show that foreign-owned companies obtain a greater return on their R&D investment compared with domestically owned companies.

[1] Boskin and Lau (2000), in a comprehensive empirical analysis, found that more than 50 per cent of the economic growth in the G7 countries (with the exception of Canada) over the past 50 years can be attributed to technological progress. The study is based on a test of a production function specifying three production factors: labour, physical capital and human capital.

[2] Salter and Martin (1999).

[3] See OECD (2001a), Sakurai 1996, and Boskin and Lau 2000.

[4] Jones and Williams (1998).

[5] David, Hall and Toole (1999).

[6] The substitutive effect of public investment in R&D in relation to private R&D investment corresponds to what, in other studies, is designated more generally as the "crowding-out effect".

[7] Toole (2000) and Cameron (1998) find a lag of 17-19 years and 20 years, respectively.

[8] Salter and Martin (1999) refer to a number of studies that indicate that companies usually invest more in applied research.

[9] Arundel and Geuna (2001) conclude this on the basis of a study that covers 612 companies' responses to a comprehensive questionnaire about innovative activities from 1990-92.

[10] Cohen and Levinthal (1989) and Beise and Stahl (1999), among others.

[11] For example, in a study based on data for French companies, Hall and Mairesse (1995) find that an increase in the R&D capital apparatus of 1 per cent can lead to a rise in the companies' productivity of 0.25 per cent. See also Griliches (1995) for the aggregate return rates.

[12] Coe and Helpman (1995).

[13] Salter and Martin (1999), Arundel and Geuna (2001) and Jaffe (1989).

[14] Cameron (1998) also refers to studies of patents cited in new patent applications that show that innovation depends especially on existing knowledge within the same country or region.

[15] Arundel and Geuna (2001) have also examined the significance of geographical spillovers in a study of 615 of the largest European industrial companies. The study compares the significance of the geographical proximity of five different sources of knowledge and innovative activities in private companies: 1) *public research institutions*, 2) *suppliers*, 3) *customers*, 4) *joint ventures* and 5) *competitors*. The study covers innovative activities from 1990 to 1992.

[16] Jaffe (1989) examines American data for 1972-77, 1979 and 1981 from 29 states, aggregated within the individual states. There is some uncertainty in the results, as geographical proximity is defined only within the individual states, although there are actually many cases of proximity across state borders when research institutions and companies are located close to the border between two states.

[17] Microdata from 515 US companies are included in the study, which covers the years 1972-95.

[18] For example, Beise and Stahl (1999) find in German data in particular no clear correlation between geographical proximity to research institutions and the occurrence of innovations in companies. The differing conclusions could be a sign that there are structural or cultural differences between countries that affect the degree of informal exchange of knowledge between research institutions and companies in a specific country.

[19] Competence clusters, or Michael Porter's "industrial clusters" (1990), describe a set of companies and organisations that are located in a relatively small area and are bound together by very specific, specialised relations in a complex mixture of competition and collaboration. Clusters are a phenomenon that have attracted increasing attention in recent years, and countless empirical studies have been conducted, including a Danish study by the Agency for the Development of Trade and Industry (2001).

[20] Cincera and Pottelsberghe (2001) point out a number of problems that future empirical studies should address, for example, how foreign R&D capital is usually calculated in the studies according to special weighting systems. Other problems are how one perceives the mechanism through which the transfer of knowledge takes place and the difficulties of the often very low-quality data for R&D capital in countries outside the OECD.

[21] Nadiri and Kim (1996) examine the specific differences among the G7 countries in the importance of international spillovers compared with each country's own R&D. They find that international spillovers are of much greater significance for Italy and Canada than they are for Germany, Japan and the USA. The United States is clearly the country that is least dependent on other countries' R&D, and its own R&D is estimated to be six times more important than outside R&D, while Italy's is only 0.3 times as important (that is, Italy's return on international R&D is estimated to be approximately three times as great as the return on its own R&D). But the relations between countries might have changed significantly since 1991, when this study's data period ended.

[22] Fagerberg (1994), Lundvall (1992), Salter and Martin (1999), and others.

2.4 Education

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A central characteristic of the knowledge society is that the labour force's qualifications are considered very important for understanding economic growth at companies and in society as a whole. When one seeks the causes of economic growth, education is therefore one of the essential areas to examine closely (see, for example, OECD 1996 and 2000c).

It is well documented that there has been a rising demand for highly educated labour in recent decades, while the case is the opposite for the less educated (Elmeskov and Scarpetta, 2000). This great demand was succeeded by a rise in the supply of highly educated labour, and the population as a whole has become better educated. That is, the amount of human capital in the society has grown. Those with less education are being pushed out of the labour market at the same time that there is a growing need for highly educated employees to hold positions in the more knowledge-based economy (Council of Economic Advisers, 1997).

At the end of the 1980s, the American economist Robert E. Lucas published a frequently cited article in which he argues that sustained economic growth depends on a constant expansion of the human capital that exists in society.[1] In his important contribution to new growth theory in 1990, Paul Romer chose a similar approach. He stresses that the level of human capital in a society is a condition for companies' R&D and thus for long-term economic growth. According to this theory, one can thus increase economic growth by strengthening human capital.

Labour and education contribute to productivity

When one considers the relation between the labour force and growth from a theoretical economic perspective, the causes of GDP growth per capita can be divided into three components (Elmeskov and Scarpetta, 2000):

> *Demographic factors:* the percentage of persons in the labour force in relation to the entire population. For almost all OECD countries, however, demographic factors have little bearing on economic growth, mostly because they have not changed significantly.

> *Composition of the working population:* the percentage of persons of working age who are either employed or unemployed. Changes in this figure can explain changes in the GDP per capita in the 1990s, but there are large differences among the OECD countries. The percentage of the working population has risen in the USA and Japan, while it has fallen in the EU as a whole, albeit with substantial differences from country to country. According to Elmeskov and Scarpetta, low utilisation of the labour force and high unemployment in Europe are the essential causes of persistently lower growth level than in the USA.

> *Changes in labour productivity:* this made a significant contribution to changes in GDP per capita in the 1990s in the OECD. Since the number of working hours per week per employee has been declining, productivity per working hour has risen. A higher average level of education and a higher level of human capital contributed to this development.

The breakdown of the labour force by education and sectors is also significant for the return to society. Previously, the restructuring of business and industry from less productive to more productive sectors could explain a substantial portion of the growth in economic output and productivity. This was not the case in the 1990s, however, when growth was owing rather to improvements in productivity in the industrial sectors that are referred to by Elmeskov and Scarpetta. Thus, the change in productivity did not derive from distinct changes in the structure of business and industry in the 1990s.

It is crucial that no imbalance between supply and demand arises in the labour market if one wishes to realise growth potential by increasing the level of education. Romer (2000) has demonstrated this in the American context. In Denmark there have also been a number of studies and projections of the balance between supply and demand of educated labour in various educational segments.[2]

The social return on education

The relation between education, productivity and economic growth has attracted much attention from researchers in recent years. There are considerable challenges related to evaluating the relationship. A prime reason for this is the substantial statistical challenges that are involved in calculating a country's human capital. It is more than simply the level of education and work experience, which are two of the frequently used approximations of the concept.

It is difficult to put precise figures on the relation, and the statistical uncertainty is great. Nevertheless, there is clearly a positive correlation, concludes Temple in OECD (2000c). This conclusion was reached on the basis of a review of a number of empirical studies of the correlation between investment in education and the effects on productivity and economic growth.

Regression analysis of economic production functions is a very commonly used method of evaluating the correlation between education and growth. These analyses test the statistical correlation between growth and productivity on one hand and human capital on the other. The following results can be emphasised:

> OECD (2001c) examined whether the accumulation of human capital in 21 OECD countries could explain economic growth in the period 1971-98. The OECD finds a positive correlation and estimates the long-term social return on production by increasing the average level of education by one year to be about 6 per cent.

> The OECD, in a study from 1994, estimated that an increase of one year in the average length of education would increase productivity by 5-10 per cent.[3]

> Finally, Mankiw, Romer and Weil (1992), in an often-cited study, find that labour force productivity will increase by about 50 per cent if investment in human capital as a percentage of GDP is doubled. The data on which the conclusions are based, however, suggest that the results should be evaluated with caution (OECD 2000c).[4]

Growth accounting is another method of evaluating the significance of education. Growth accounting divides economic growth into contributions from changes in production factors such as capital and labour. The part of economic growth that cannot be attributed to production factors is called productivity growth and is attributed to technological development. Many studies of this type have been conducted.

In this respect, Temple in OECD (2000c) refers to a study by Maddison of six OECD countries (not including Denmark). Maddison approaches an estimate of human capital by distinguishing between labour in three educational categories. The three categories are combined in an index of the quality of the labour force through the use of weightings that are uniform over time for the six OECD countries. The results show that changes in the quality of the labour force contributed about 0.1-0.5 of a percentage point to annual growth rates from 1950 and 1984.

In another study, Jorgenson and Fraumeni (1992) examined the average annual growth rate in the USA in the post-war period. Of an average rate of 3.29 per cent, about 0.25 of a percentage point could be attributed to changes in the quality of the labour force. This is equivalent to that one-tenth of economic growth can be attributed to higher quality in the labour force.

In a Danish study of the relation between education and economic growth from 2001, Hougaard Jensen and Sørensen (2001) document that in the period 1980-98 there was a shift in demand in business and industry, with an increase in the demand for highly educated labour. They also evaluated the effect of this shift and concluded that there was a large contribution to growth from the relative change to greater demand for educated labour. It amounted to at least 15 per cent of economic growth in business and industry in the period 1980-98.[5]

Altogether, the studies show that there is a positive correlation between educational level on one hand and productivity and economic growth on the other. However, there is a significant limitation in the methods used, however, as the economic models have difficulty capturing all the growth effects and effects on social welfare that originate in changes in the level of education. A prime reason for this is the statistical difficulties of incorporating the many factors, such as adult education, learning and network relations, that contribute to the amount and effect of the human capital in a society. Altogether, there are therefore good grounds for assuming that the estimates presented actually underestimate the significance of human capital for the productivity of labour and for developments in social welfare (OECD, 2000c).

[1] Robert E. Lucas (1988).

[2] See, for example, Groes, N. and Holm, A. (1999). Ministry of Economic and Business Affairs, Ministry of Education, Ministry of Research and Information Technology and Ministry of Labour (2001), Danish Research Academy (1998), Academy of Technical Sciences (1996), and Ministry of Education (1996).

[3] The study is referred to by the Ministry of Finance (1998).

[4] Such estimates must of course be interpreted conservatively. In the study by Mankiw, Romer and Weil cited, the results were subject to substantial statistical uncertainty, although the method was relatively simple. A significant limitation in such studies is the large differences in social structure that exist between the countries included in the studies (OECD, 2000c).

[5] The growth accounting model that Hougaard Jensen and Sørensen use differs from the type that is normally used in the literature in that it is based on the assumption that technological development is directed towards educated labour, making the growth accounting model dependent on the educational structure. Consequently, it is not possible to distinguish the effect of the educational structure on productivity growth, as it is determined as the difference between output growth and growth in the input factors. The result therefore shows the change in the quality of labour, and this is the lower limit for the effect on growth of the shift in relative demand.

Higher education has a positive influence on the economy >

Name: Svend E. Hougaard Jensen
Position: Head of Research, Centre for Economic and Business Research (CEBR), Ministry of Economic and Business Affairs; Senior Researcher, Economic Policy Research Unit (EPRU), University of Copenhagen.

At least 15 per cent of the growth in Danish production in the period from 1980 to 1998 can be attributed to the fact that companies sought and hired an increasing number of highly educated employees.

This is shown in new Danish calculations (Fosgerau, Jensen and Sørensen 2000 and Jensen and Fosgerau 2002) that were conducted for the purpose of assessing whether a higher level of education can stimulate economic growth and thus avert some of the negative economic effects of the decision by an increasing number of older workers to take early retirement.

On the basis of previous results in the literature, there was little to indicate that the growth contribution from education was very large. But with new and better data, the result was 15 per cent, which is certainly not insignificant.

One must therefore expect that there will be political initiatives to influence the labour force to postpone retirement through changes in the pension system and to promote investments in human capital.

An international phenomenon

The rise in demand for highly educated labour in recent years is an international phenomenon, while the demand for less educated workers has declined.

The Western economies, however, have not reacted uniformly to this shift in demand for specific categories of labour. In the USA, it has led to larger disparities in income, while in Europe the adjustment has usually taken place in the form increasing unemployment among unskilled workers, whereas changes in the payroll structure are modest.

Fosgerau, Jensen and Sørensen (2000) and Jensen and Fosgerau (2002) determined the extent of this shift in demand in Danish business and industry. The calculations were made by means of the IDA database that covers the entire Danish population broken down by a number of personal characteristics, including 29 educational categories.

The articles show that the shift in demand is generally of the same magnitude as in the USA in the period 1980-98. They also show that demand rises with the level of education; that is, the more advanced the degree, the more demand has risen.

Growing interest in humanists

The research also shows that the growing demand has expanded the spectrum of educational backgrounds in which the business community is interested.

While companies hired mainly engineers in the beginning, during the period an increasing number of humanists, natural science graduates and others succeeded in obtaining positions in business and industry.

You can read more here:

www.cebr.dk/shj.htm

Fosgerau, M., S.H. Jensen and A. Sørensen. 2000. "Relative Demand Shifts for Educated Labour." CEBR DP 2000-11, http://www.cebr.dk/.

Jensen, S.H., and A. Sørensen. 2002. "Uddannelse, beskæftigelse og økonomisk vækst." *Nationaløkonomisk Tidsskrift*, vol. 140, pp. 1-17.

2.5 The interaction between universities and the business community in innovative networks >

Collaboration in complex network structures increased sharply during the 1990s. Companies can no longer cover all disciplines, and they therefore need to specialise their activities and to an increasing extent complement own competencies through collaboration with other companies or public research institutions. The positive effects of such networks are a sharing of costs and risks, an increased ability to manage complex issues as well as greater capacity and specialisation in comparison with their own activities (OECD Policy Brief, 2000).

The increasing tendency towards collaboration on innovation is also evident in the fact that companies today rarely pursue innovation alone (OECD Policy Brief, 2000).

Collaboration and networks between the public sector and the business community often build upon personal contacts. Such networks promote an ongoing exchange of ideas, knowledge and information. Both OECD researchers and those concerned with innovation theory have suggested that informal networks and interaction are of vital importance in the exchange of knowledge. This is true of relations not only between the public and private sectors, but also between companies in the private sector.

After the past 20 years' research on innovation, there is now an understanding of innovation as a process that involves a complex interaction between universities and companies through the entire cycle.[2]

Concrete evidence of the interaction between universities and companies can be found by considering the trend in scholarly articles with authors from both universities and companies. Such a calculation shows a clearly upward tendency. For example, Godin and Gingras (2000) who, using Canadian data, showed that the number of articles with both types of author nearly doubled from 1980 to 1995. This suggests increased collaboration between the two sectors. Several studies also indicate that the informal relations between universities and the business community are important.[3]

Research and patents

Bibliometric methods can measure whether publicly financed research has an influence on industrial research and development. One commonly used method is identifying references to scholarly articles in industrial patent applications. Patent applications can lead to actual innovations, and it is therefore interesting to see whether patents are developed on the basis of publicly financed research.

Jaffe (1989) examined the direct effect of academic research on industrial development on the basis of the number of new industrial patents.[4] The conclusion is that academic research appears to have a significant effect on the number of patents that the industrial sector produces. The result suggests that patent activity grows by 10 per cent when the research increases 100 per cent. Of even greater importance, however, are the indirect effects, as more public research stimulates more industrial research. In fact, it is estimated that an increase in public research by 100 per cent will indirectly increase the number of patents by 60 per cent.

In another study, Narin, Olivastro and Hamilton (1997) calculated the number of references to scholarly articles in American patent applications from industrial companies in the period 1993-94. They found that 73 per cent of the references were to articles from public research institutions.[5] Their studies also show a sharp rise in the number of references to scholarly articles in US patent applications. This indicates that the industrial sector depends very much on public research institutions. The authors conclude that publicly financed research is an important source for development in high technology industries.

The studies thus show a positive correlation between publicly financed research and industrial patent activity and emphasise the importance of public research institutions. One point of criticism of the results of these studies is that the relation between research results and patents is not as clear as such a treatment of the data indicates.References are not always an indication of a close relation between patents and research results. In some cases they should rather be seen as providing inspiration - or as a means of increasing the scientific value of the patent.

Research and innovation

Empirical studies show a clear and positive correlation between scholarly articles and industrial patents. But it is difficult to determine the effect that public research has on the number of industrial innovations. The methods that have been used thus far have been based mainly on questionnaires given to companies. The results suggest that up to one-fifth of companies' innovations can be linked to research conducted by public research institutions. However, the following studies are the most credible regarding the larger and more research-intensive companies.

Tijssen (2001), in a study based on a questionnaire given to Dutch researchers and developers in both the public and private sectors, shows that about 20 per cent of the innovations in business and industry are based partly on research from the public sector.

Mansfield (1998) conducted a study of 76 research-intensive US companies in 1991. The study was repeated in 1998 with 70 companies. In the more recent study, Mansfield found that about 15 per cent of all new products and about 11 per cent of all new processes, measured over a 10-year period, would not have been developed without academic research - or in any case would have been developed only after a substantial delay. On the basis of these results, Mansfield estimates that the innovations that derived from academic research made up about 5 per cent of the companies' sales. The result must be viewed with some reservations, however. One reason is that it cannot be said to be representative, as it is based only on assessments from business leaders in large American companies. In addition, the study examines only the effects in the United States.

Beise and Stahl (1999) conducted a similar study of German data with a much larger sample of companies. The study covers 2,300 German companies over the period 1993-95. The result is that 10 per cent of the companies that launched product or process innovations in the period would not have done so without publicly financed research. This corresponds to about 5 per cent of total new product turnover.

In contrast to Mansfield, Beise and Stahl also include small companies in their study. They can therefore conclude that small companies make less use of university research than large companies. Although the authors make certain reservations[6] regarding the solidity of their study, they nevertheless conclude that the results argue against the view that specific industrial innovations in themselves can justify publicly financed research in Germany. The justification of publicly financed research seems rather to be that universities, partly through informal relations, are important sources of new knowledge - and that universities provide research personnel to the industrial sector.

Many studies of the economic return on public investment in R&D emphasise the significance of the education and training that is associated with public research institutions. The training of graduate students and researchers who later assume positions in business and industry contributes not only concrete technical knowledge but also the competency to conduct research-based tasks and solve complex problems. In an older study, from 1974, Gibbons and Johnston examine the significance of public investment in research and development. They conclude that well-educated graduates are one of the most important contributions from such investment. Newer studies seem to support this conclusion.[7]

The growing tendency to hire highly educated graduates in business and industry does not come without problems, however. Companies often need to invest significant time and resources before they can take advantage of the potential of new graduates. According to Salter and Martin (1999), it is therefore crucial to ensure both a close linking between research and education and an ongoing dialogue between the public and private sectors in the educational process. Altogether, the empirical studies suggest that, regarding the correlation between publicly financed research and innovation, only a rather small number of innovations arise from research. The indirect effects, in the form of informal relations and education, however, can be important, although they are difficult to measure.

Entrepreneurs and innovative environments

Small start-up companies in high technology fields are one factor that is often mentioned in connection with the knowledge society. Such small companies are often more flexible than larger ones, contribute to the renewal of the business community, and are sources of new knowledge and new ideas in the economy.

Provisional figures from the OECD show that new companies are rarer in Europe than in the USA, where there are three or four times as many small start-up companies as in other OECD countries. This is especially true in IT and biotechnology, which are very important sectors in the knowledge economy (OECD Policy Brief 2000).

It is often stressed that public investments in research promote the creation of new high technology companies. There are good examples of this in areas surrounding large research institutions such as Massachusetts Institute of Technology (MIT) in the USA and Oxford University in the United Kingdom. Nevertheless, Salter and Martin (1999) show that it is difficult to demonstrate a correlation between investment in research and the founding of new companies. The authors refer to a study by Bania from 1993 that finds a positive correlation in the electronics industry but not in other sectors.

The effect of investing in innovative networks

The main effect of investing in knowledge and in strengthening innovative networks is therefore more precisely that it creates better conditions for the development of new knowledge and a more effective utilisation of the knowledge that already exists.

Lundvall (1992) has stressed the necessity of public investment for the purpose of generating new forms of interaction between players in the national knowledge system. These include research institutions and companies. He argues that the learning necessary in connection with innovations is promoted through institutions that can create contact among various players. One reason for this is that innovation can be described as an increasingly social process. It is therefore necessary to be able to access and utilise the knowledge that exists in the network.

In another study from 1994, Callon argued that public investment in the knowledge society must be seen as a way of establishing new networks. The financing can stimulate new relations and new forms of collaboration. The market will tend to use up the natural variation that exists in society, and this leads to greater uniformity and locks technological development into specific paths. Through public financing, it is possible to break such a development and create new knowledge and new opportunities for companies, and together these developments will increase companies' competitiveness.

[1] See for example Lundvall (1992) and OECD (1996).

[2] See for example Kline and Rosenberg (1986), Lundvall (1992) and the Agency for Development of Trade and Industry (1999).

[3] For an overview, see Salter and Martin, 1999, and Scott et al., 2001. Salter and Martin (1999) refer to a study by Arundel, Soete and van de Paal from 1995, in which 640 large European companies were asked to evaluate the various public sources of knowledge. The results show that the three most important sources of new knowledge from public research institutions are publications, informal contacts and the hiring of employees, in that order. The results strongly support the view that public research is not only a question of increasing the amount of knowledge in society but is just as much a question of creating the opportunity for mutual learning between the public and private sectors.

As mentioned above, these effects seem to be reinforced by geographical proximity. They were therefore tested with a model that uses the number of patents as the response variable; uses the budget for academic research and the budget for research financed by industry as the explanatory variables; and uses a component that weights academic research with a measure for the geographical proximity between industrial R&D and the public research institutions in the central government.

[5] The study must be interpreted with caution, however, because, in order to ease the data processing, it references only scholarly articles published in a single year (1988).

[6] The most important reservation concerns the fact that only specific innovations based on public research that companies have registered are included, while contributions from the general volume of public research are not. In addition, the authors note that the companies, in their calculation of the effects, probably measured only the short-term effects. Thus, the results appear to underestimate the actual total effects of public academic research on industrial innovation.

[7] For example, Arundel, van de Paal and Soete (1995) show, through a survey of 640 companies, that 44 per cent consider the hiring of new graduates to be a very important source of knowledge about research results.

Danish innovation policy yields results

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Name: Anders Sørensen
Position: Assistant Professor, Johns Hopkins University - SAIS, International Economics Department, Washington, DC, USA and researcher at the Centre for Economic and Business Research (CEBR)

Danish innovation policy is effective because it increases the volume of private R&D investments in Danish manufacturing companies.

Increased R&D is in the interest of society

Companies' R&D investments result in the creation of new manufacturing processes and products which have a positive effect on productivity. Furthermore, R&D leads to the dissemination of knowledge insomuch as companies learn through the knowledge and know-how of other companies.

The public authorities are working to increase private investments in R&D because knowledge created through R&D investments over time turn into a collective benefit, i.e. something which can be used by other persons than those who used it for the first time.

To put it another way, the socio-economic return on investment in R&D is higher than the private economic return, which leads to a volume of private investments that is less than what is desirable from a societal point of view.

Without public incentives, the extent of private R&D activities would therefore typically be less than what is socially desirable but it is unclear what form a public policy to further R&D should take. Traditionally, three different instruments have been put into play to further private, business-related R&D activities, namely tax-based subsidies, direct public financing and direct public control through R&D programmes.

In Denmark, the main focus has been on the latter two instruments. The majority of public innovation initiatives are aimed at the private sector through the network of Authorised Technological Service Institutes (GTS institutes). In addition to this support, direct subsidies are awarded to R&D activities.

Strong positive correlation

Sørensen, Kongsted and Markussen (2003) shed light on two issues relating to Danish innovation policy. The first is the question of whether public innovation initiatives have had any demonstrable effect on the private incentive to invest in R&D. More specifically, they studied whether there is a demonstrable correlation between *public innovation support* and the extent of *private R&D investments* in the manufacturing sector.

Since the results suggest a strong positive correlation, the article raises another question, namely whether Danish innovation policy also translates into increased productivity.

The ambition of this part of the study is to determine whether public innovation financing has an indirect effect on the long-term productivity in the manufacturing sector, through R&D. The article demonstrates a positive correlation, though relatively weak, which is a result that often appears in the literature.

You can read more here:

Anders Sørensen, Hans Christian Kongsted and Mats Marcusson (2003), "R&D, Public Innovation Policy, and Productivity: The Case of Danish Manufacturing" *E, Economics of Innovation and New Technology*, forthcoming.

2.6 IT and telecommunications >

The Internet and information technology distinguish themselves from most other innovations by being extremely widespread in almost all aspects of commerce and production, in the entire educational system, in the public sector and in the private home. The IT revolution has been compared to other major technological revolutions such as the discovery of electricity and the steam engine.[1] Various studies seek to determine to what extent IT will have the same consequences in the form of large jumps in economic growth.[2]

Recent studies suggest that IT has led to strong growth in the IT sector and has also contributed to increased productivity and productivity growth in the economy in general.[3] A concept that is used in this context is the "new economy". The new economy is defined in different ways by different authors in the recent literature. But the term basically describes an economy in which IT and related investments give rise to higher productivity growth rates.[4] There is no doubt that in many ways IT has revolutionised the economy, causing major changes in the production system, the educational system and, in some respects, the entire society. One speaks also of the networked society.

The term "networked society" carries an almost direct reference to the transfer of knowledge that IT can be the catalyst of.[5] IT thus plays a role at many different levels. It begins with the fundamental form of new physical capital in companies: IT as equipment. And it continues by making possible much faster communications and new collaborative forms and processes. IT can support the human learning process, and it has become a central element in many educational contexts.

In several studies, the OECD has concluded that IT often has the character of a technology that, besides being a factor in individual products, is able to contribute to increased efficiency in other products.[6]

The significance of IT can be summed up in the following points:

> IT has helped to break down the monopolistic tendencies in telecommunications and has thus led to major investments in innovation.

> IT has helped to increase the pace of innovation because of information exchange and increased flexibility - and because IT causes a closer correlation between company strategy and economic productivity.

> IT has created more networks in the economy.

> IT has led to increasing globalisation because of easier access to information.

> IT makes it possible to quickly spread knowledge and research, both within and across national borders.

> IT has helped people better exploit the results of research, partly by binding research and companies more closely together.

> IT makes it possible to make the public sector more efficient.

It is therefore difficult to determine how IT must be perceived and analysed. Must IT simply be treated as a new form of capital? Or must IT rather be seen as an element in total factor productivity (TFP), perhaps the dominant element?

The effect of IT in the USA

Until recently, studies of the significance of IT ran up against the paradox that several years' increased investments in IT could not be seen as productivity improvements, despite the fact that this was the general reason for making the investments.[7] The seeming paradox disappeared in the mid-1990s when productivity improvements rooted in IT were demonstrated. A Danish study by Gjerding et al. as early as 1990, however, indicated that a lack of organisational renewal and problems with the upgrading of employees' qualifications were the essential causes of the absence of productivity effects.[8] The correlation was examined in an OECD report (1999b).[9] This led to the formulation of a model that explains the seeming productivity paradox. In this model, IT takes the form of strengthened productivity with a certain lag in time because there are costs involved in learning. Companies must first implement new systems, and the employees must be trained to use them before there are economic gains.

In the USA, this strengthened productivity became apparent in the mid-1990s. The 2002 edition of the annual report The Digital Economy from the US

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Chamber of Commerce concludes that IT was the crucial factor in productivity growth since 1995. By means of a rather simple consideration of growth in labour force productivity in American business and industry between 1989 and 2000,[10] the report finds that the annual productivity growth of 1.68 per cent for the economy as a whole was owing exclusively to the half of business and industry that used IT to the greatest degree. The most IT-intensive industries had an average annual productivity growth of 2.95 per cent. In comparison, the half of business and industry that did not use IT as much only contributed 0.58 per cent.

Elmeskov and Scarpetta (2000) found several studies suggesting that strong growth in productivity in the IT sector affected productivity growth in the overall economy. This is especially true in the USA, which, aside from Japan, is the country where the IT sector accounts for the largest share of GDP.

IT investment in the USA annually rose 24 per cent in the period 1990-96. Total IT investment in 1999 amounted to 35 per cent of total capital investment in the USA (Elmeskov and Scarpetta 2000). The contribution of IT capital investment to GDP growth increased throughout the 1990s. IT capital accounted for 1.1 percentage points of GDP growth in the USA, or a total of 4.6 per cent annually in the last half of the 1990s.

Jorgenson, Ho and Stiroh (2001) believe, however, that the contribution from IT in the same period was only 0.8 of a percentage point despite including several types of IT investment in the analysis. Such analyses should therefore be regarded not as exact calculations but perhaps as an indication of the interval within which the effect might be supposed to lie.

Sustained or temporary acceleration of growth?

There are other crucial questions in assessing the significance of IT. For example, if there has been a fundamental shift in productivity to new growth levels because IT permanently increases growth in the productivity of labour and capital? Or if it is rather a case of a one-off gain in a period with high growth rates while IT is introduced and rationalises work procedures once and for all, followed by a period in which the economy levels off and returns to a lower growth rate.

Gordon (2000) has investigated this issue and determined the significance of IT through changes in TFP growth. In the US durable consumer goods sector, there were explosive growth rates in the period 1995-99. Gordon finds that these primarily can be attributed to direct or derivative effects of growth in IT. One part of the acceleration in TFP growth appears to be of a structural, permanent character. On the other hand, Gordon surprisingly finds that the increase in TFP growth in the rest of the economy has only the characteristics of a cyclical effect. When the durable consumer goods sector's share of growth is not included, there was actually *declining* growth in TFP for the rest of the economy.

Accordingly, the analysis concludes that the IT industry alone achieved increased TFP growth, but that there did not appear to be any sustained change in productivity growth for the other sectors. Such an analysis must be viewed with certain reservations, however. First, because the division of productivity growth into structural and cyclical parts is necessarily subjective, and second, because one cannot rule out that there still might be a certain delayed effect that could mean an underestimation of the sustained effect.[12]

IT effects in Europe and Denmark

Elmeskov and Scarpetta (2000) believe that IT capital will have a similarly increasing significance for the economic growth in Europe. But this cannot yet be documented statistically, because it is more difficult to examine the effects of IT in Europe. One essential reason is that the USA was the leader in IT at a very early stage and thereby built up by far the largest real IT industry. The Ministry of Finance (2001) mentions that productivity increases in the US IT-producing industry contributed 0.3-0.4 of a percentage point annually to total growth, while the corresponding figure for Denmark was only 0.1 of a percentage point.

The USA's leadership in the IT area therefore also implies that it is difficult to judge the significance of IT in Europe, as there is a certain lag in comparison with the development in the USA.[13]

The European Competitiveness Report (2001) documents that there is a sharp difference between the level of IT investment in USA and EU. The business community's IT investment in 1999 was 4.5 per cent of GDP in the USA and only 2.4 per cent of GDP in EU. This difference has declined in recent years in individual EU countries, including Denmark.[14] Studies estimate that in the European countries IT has on average contributed 0.4-0.5 of a percentage point of production growth, while the figure is 0.8-1.0 of a percentage point in the USA.

Hougaard Jensen and Sørensen (2001) conclude that it is still too early to determine whether Denmark has experienced the effects of the new economy.

How are the effects of IT realised?

The OECD's Policy Brief (2000) concludes that in the OECD countries generally IT gives rise to large gains when it is combined with other investments in strategic and organisational development as well as with the education/training of employees. The European Competitiveness Report (2001), OECD (2001a) and Verspagen (2000) confirm this.

Verspagen (2000) has analysed the differences in labour productivity in the USA and the other OECD countries. Verspagen points to the fact that IT might be decisive in bringing about a convergence of the OECD countries' productivity, that is, in enabling the weaker countries to catch up to the stronger ones. The conclusion is that IT can either advance or hamper such a catch-up process, depending on whether the countries understand how to adjust to new technologies and exploit the opportunities of IT as well as possible.[15]

Other studies also find that IT investment is dependent on education. That is, IT creates a need for more highly educated labour.[16] Part of the economic benefits of IT consists in being able to digitalise some of the most routine-characterised tasks.

OECD (2002) confirms that one of the most important focus areas for politicians and companies should be the gap between some IT employees' present qualifications and the qualifications that business and industry need.

[1] These large technological conquests with thoroughgoing consequences for society are mentioned under the collective heading of "General Purpose Technologies" and are treated by Helpman (1998) and others.

[2] For example, Gordon (2000).

[3] The European Competitiveness Report (2001), OECD (2000a), OECD (2001), Hougaard Jensen and Sørensen (2001a).

[4] This definition adheres to the one in the Digital Economy (2002). OECD (2000a) defines "New Economy" somewhat more broadly as follows: "The association of inflation-free growth with computerisation and globalisation, with the implication that information technologies play a major role in explaining sustained growth. The notion of the 'new economy' has also been employed to signal that the workings of the economy may have significantly changed…."

[5] The OECD Policy Brief (2000) describes how IT in the OECD countries has contributed significantly to increased network collaboration between companies by reducing costs through outsourcing and collaboration.

[6] See, for example, OECD 2000a, 2000c and 2001a.

[7] This paradox was called the Solow paradox because of a statement by Robert Solow (1987).

[8] The conclusions of Gjerding et al. (1990) were based on a comprehensive interview study using Danish data. The lack of productivity effects seems to arise from the fascination with technology that characterised decision makers in Danish companies in the mid-1980s. Both experts and company leaders suggest that in this period people placed far too much emphasis on technical solutions and underestimated the need for organisational renewal. In addition, the study indicated that "the organisational and staff problems, for example qualification problems, have the most negative effect on the profitability of high technology investments".

[9] OECD, Ahn (1999b), on the basis of US data from 1,031 companies in the period 1986-95 compared the rate of investment in IT with the growth in TFP and found a negative correlation. That is, increased IT capital had the immediate effect that TFP declined, and Ahn associates this with the so-called "learning cost". In the first years after substantial investments in IT, productivity will go down because people and systems must adjust to the new technology.

[10] Productivity is calculated here as total output (GDP) in relation to the total number of employees converted into full-time equivalents (FTE). This measure, GDP/FTE, is calculated for all industries. Afterwards, the average productivity is determined for two groups of industries, which each make up 50 per cent of GDP: one consists of the most IT-intensive industries and the other consists of the least IT-intensive industries.

[11] This was concluded on the basis of an analysis in which the decline in unemployment is divided into a supposedly permanent part and a more cyclical part. The estimated permanent part of productivity growth in the general economy was thus not affected positively by the explosive development in IT and related industries.

[12] Again, one must also note that the analysis of the significance of IT is based on the relatively rough model with IT as partly capital input (that perhaps does not even include software) and partly a more diffuse portion of TFP growth. All estimates are therefore probably too low.

[13] DOECD (2000a) confirms this in a study that investigated IT's share of TFP for the G7 countries but did not find signs of growth in TFP in the period 1985-96. This is a significant limitation in the data, as TFP can be calculated only until 1996 for the G7 countries, but other studies have shown considerable growth in TFP since then. As mentioned above, another significant limitation of the OECD's study is that only IT hardware is included in IT capital.

[14] The UK and Sweden have now surpassed the USA in IT investment as a percentage of GDP, and Denmark, the Netherlands and Ireland have approached the investment rate in the USA; a number of other large countries lag much further behind.

[15] The article is based on an empirical study in which the productivity growth of the OECD countries is broken down into two factors: technological and structural changes. The technological component represents productivity growth in sectors, while the structural component covers cross-sector shifts in the allocation of labour. Afterwards, the various sectors' shares in the convergence period and the period with declining convergence are analysed. This shows that the clear convergence between the USA and the other OECD countries in the 1950s and 1960s in particular took place primarily in the manufacturing sector. The reason is that this technological revolution involved mass production. The technological conquests were achieved by the USA in the 1920s and 1930s, but because of the Depression and World War II, they were not exploited intensively in the other countries until the post-war period. In the 1970s and 1980s, the convergence trend gradually subsided, but the article's empirical studies suggest the possibility of a new era of productivity convergence borne by the possibilities of IT technology. The beginning tendencies can be seen in 1994-96, especially in the financial, insurance and mortgage finance sector, which was heavily affected by IT systems.

[16] Sørensen and Hougaard Jensen (2001), for example, adduce that IT is "skill-biased" and refer to a number of other studies that document this effect in the USA, other OECD countries and Denmark.

IT as an instrument for knowledge management - also among companies >

Name: Mogens Kühn Pedersen
Position: Professor, dr.merc., Department of Informatics, Copenhagen Business School

Originally, knowledge management was developed to make knowledge sharing within the individual company more efficient. The focus was on local work processes with a view to achieving “best practice”. Today, however, the focus is also on customers and suppliers beyond the walls of companies. This takes place in recognition of the fact that many internal work processes depend on these players - and with a confident expectation that IT will make supply and sales channels more efficient.

Within these networks, distributed IT systems are synonymous with improved coordination and faster transactions.

At the Copenhagen Business School, we are working to develop models for knowledge exchange within distributed systems. The purpose of distributed systems is to make the entire set of transactions between companies more efficient, rather than to focus solely on the individual transaction.

The relevance of such systems is, for example, illustrated in the state public health system in the USA. Greater patient satisfaction and improved efficiency has been achieved by providing health services to persons under the public health scheme. At the same time, the system has given health authorities insight into the effect of health services over time.

Thus, distributed knowledge systems also have a socio-economic importance in that they reduce operating losses and unsuccessful investments in connecting, complex networks of companies and institutions.

You can read more here:

www.cbs.dk/~mogens.kuhn

M. Kühn Pedersen and M. Holm Larsen, Distributed Knowledge Management Based on Product State Models - The Case of Decision Support in Health Care Administration. *Decision Support Systems*, 31 (1) 2001, May 139-158. Special issue on Knowledge Management Support for Decision Making.

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> Denmark ranks among the top nations in the world, with respect to the number of scholarly publications, measured both per capita and by the resources invested in the research system.

> The total investments in R&D were DKK 32.2 billion in 2001, or approximately 2.4 per cent of GDP, which places Denmark below the countries with which it normally compares itself, such as Finland and Sweden.

> The public sector's share of total R&D investments has decreased steadily since 1991, accounting for approximately 30 per cent of the total in 2001, while business and industry accounted for nearly 70 per cent.

> Natural sciences, with DKK 2.8 billion, was the research area that the public sector invested most heavily in, during the year 2000. This is equal to 28 per cent of the total public R&D investments of DKK 9.7 billion.

> Each year, approximately 18,000 students begin university, with most (70 per cent) studying social sciences and humanities. These two groups account for 60 per cent of all Candidatus (Master programme) students.

> In 2000, 8,592 students obtained a Candidatus degree. The number of graduates has risen constantly since 1980.

> The number of PhDs has more than doubled during the past 10 years. In recent years, however, the number of entering PhD candidates has been rather stable at about 1,100.

> In 2001, total public expenditure for universities amounted to about DKK 10 billion. Of this amount, direct appropriations for education represented nearly one-third.

> Total expenditure for higher education in Denmark amount to about 1.5 per cent of GDP.

> 41 per cent of Danish companies innovated in the period 1998-2000. Investments in innovation amounted to 7 per cent of the companies' turnover. 15 per cent of the companies' turnover derived from products that were entirely new to the market.

> In the period 1995-2000, almost 100,000 companies were founded in Denmark, of which one-third were in the knowledge-service and high technology industries.

> In 1999, 25 per cent of the companies that conducted R&D collaborated with public research institutions.

> In a European context, Denmark is one of the leading countries with respect to penetration and accessibility of high-speed access to the Internet. More than half of the Danish population has access to the Internet from home.

> In the OECD's comparisons of IT and telecommunications prices, Denmark generally ranks in the top half of the countries.

> Denmark ranks as one of the world's leading countries in terms of the percentage of companies that receive orders via the Internet.

Financial statements, national accounts statistics and knowledge policy overlook the new economy

Name: Birgitte Andersen
Position: Senior Lecturer and Director for E-commerce Programme, Birkbeck, University of London; Honorary Associate Fellow, ESRC Centre for Research on Innovation and Competition (CRIC), the University of Manchester

Company executives, legislators and international bodies have a common problem. In the new economy, the figures which form the basis of company decisions and policy making are often quite insufficient. They lack consideration of the importance, function and extent of the immaterial economy.

This can have far-reaching consequences for understanding the extent and importance of the new economy as well as for forming relevant political policies. (i) It is problematic if investors cannot evaluate a company's true value since most of its assets do not appear in the accounts. (ii) It is problematic for business strategy and for the formation of relevant policies if the most essential production factors cannot be systematically identified or measured and if we do not understand their interaction with the production system. (iii) This is not only a problem which regards financial statements. If "intellectual capital" (IC) and non-material values are production factors and act as main assets in companies (as opposed to physical capital and physical labour) then it is problematic that none of these units are included in productivity statistics, which are an index for how efficiently we utilise our resources.

Such aspects are not included because financial statements and national accounts statistics are part of a conservative financial institution in which the exchange of new theories, terms and quantitative specifications takes place within a specific context. The general perception of what is important to measure is also value-based and often grows out of historical factors. The statistics simply do not take the special characteristics of the new economy into account.

Values which cannot be weighed and measured

The new economy is to a large extent an "intangible" economy where non-material factors, which are difficult to weigh and measure, play an ever more important role. These include non-material production factors, services and E-commerce as well as many company assets (e.g. knowledge, patents, copyrights, social capital networks). The growing importance of such new production structures and new ways to create values reflect the shortcomings of the official statistics.

We do not know the dynamics

Another problem is that we do not understand the dynamic effects of many of these non-material values. For example, in spite of tightenings of the Intellectual Property Rights (IPR) legislation, we do not know the economic and social consequences of the IPR system. Future focus should be on studying the rational of the IPR system, including the moral rationale, the rationale for economic incentives, the rationale for increased competition and "market protection for entrepreneurial talents" as well as the economic rationale for organising knowledge technology and creativity. We will not be able to design an adequate IPR regime for the new techno-economic paradigm until we gain a critical understanding of how the IPR system interacts with these conditions.

You can read more here:

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3.1 Research >

- Total investments in R&D were DKK 32.2 billion, in 2001.
- The public sector's percentage of total R&D investment has decreased since 1991, accounting for approximately 30 per cent of the total in 2001, while business and industry accounted for nearly 70 per cent.
- In 2001 Denmark used approximately 2.4 per cent of GDP on R&D, placing the country below Finland and Sweden, but over the average for the EU.
- 60 per cent of the public sector's R&D, took place at the universities in 2000.Government research institutes conducted 21 per cent of R&D. The remaining 19 per cent was carried out at hospitals and other institutions.
- Two-thirds of R&D in business and industry in 1999 was conducted in the industrial sector. The remaining one-third took place at service companies.
- Natural sciences, with DKK 2.8 billion, was the research area that the public sector invested most heavily in, during the year 2000. This is equal to 28 per cent of the total public R&D investments of DKK 9.7 billion.
- In 2001 Denmark ranked among the top nations in the world, with respect to the number of scholarly publications, measured both per capita and by the resources invested in the research system.

Financial resources in the research system

R&D work is a resource-intensive and often long-term process in which the funds that the public sector and companies spend must be considered investments that give both individual companies and society a large return in the longer term. In this section, we examine the public and private sectors' investments in R&D work.

Investments in research and development work

Total investment in R&D in 2001 was DKK 32.2 billion. From 1985 to 1997, total R&D investments doubled. The public sector's share of total investment declined from 41.5 per cent in 1991 to 30.6 per cent in 2001. In the period 1991-2001, total R&D investment increased by nearly DKK 15 billion, equivalent to a rise of 85 per cent.

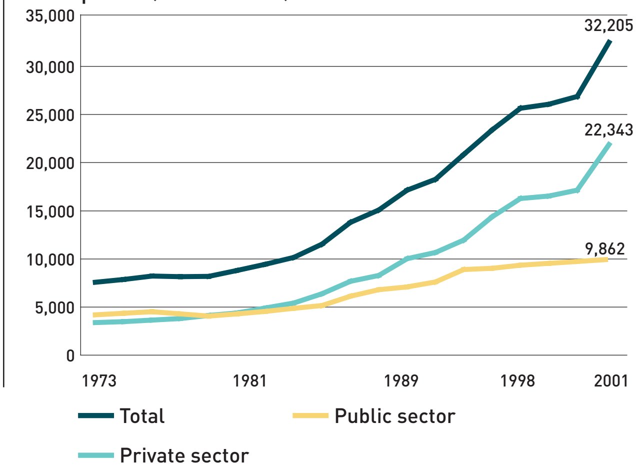
R&D is an abbreviation for research and development work. According to international convention, the concept covers the following:

Creative work done on a systematic basis for the purpose of increasing scientific and technical knowledge, including knowledge about people, culture and society – as well as the utilisation of this knowledge in practical applications.

Time series and price indices

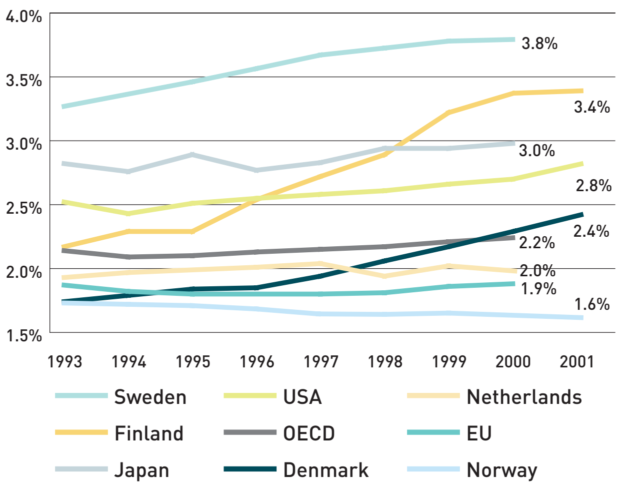
All time series in this report that contain expenditure figures are deflated to adjust for price increases. For time series involving public Budget appropriations, that is, based on the public research budget, the PL index from the Ministry of Finance has been used. For time series based on research statistics, the consumer price index was used. Although there are differences in the extent of the price increases, they are insignificant in relation to the trends presented in the report.

Figure 1: Total R&D investment by sector, 1973-2001, 2001 prices (DKK million)



Source: Forskningsstatistikken (Research statistics) 1973-2001.

Figure 2: R&D as a percentage of GDP, 1993-2001



Source: OECD - Main Science and Technology Indicators 2002:2.

Note: For Denmark 1999-2001, Finland 2001 and Norway 2001, the source is the Danish Institute for Studies in Research and Research Policy.

In 2001 Denmark used approximately 2.4 per cent of GDP on R&D. Denmark has moved above the EU average in the period shown, but still stands substantially below the leading R&D countries.

The breakdown of R&D work shows that almost one-third, or 0.7 per cent of GDP in 2001, is conducted by the public sector and slightly over two-thirds, or 1.7 per cent of GDP in 2001, is conducted by the private sector. In the countries that invest most heavily in R&D, however, the private sector typically accounts for up to three-quarters of total R&D investments.

In Denmark, the private sector is dominated by small and medium-sized enterprises that do not have enough volume to undertake substantial investments in research independently. Figure 4 shows the breakdown of the public and private sectors' research efforts by type of research. Of R&D investments in companies that conduct R&D, 80 per cent goes to development work. Some 15 per cent goes to applied research, and only 5 per cent go to basic research. In the public sector's R&D work, the ratio is the opposite, with basic research accounting for 49 per cent of research investment and applied research accounting for 38 per cent.

Who conducts Danish research?

The breakdown of public R&D investment by sector shows that nearly 60 per cent of the public sector's R&D in 2000, was done by universities, at an expense of about DKK 5.8 billion.

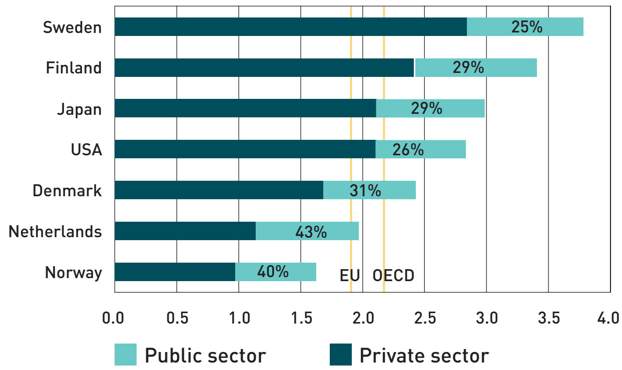
Types of research

Basic research
Basic research consists of original experimental or theoretical work with the primary objective of attaining new knowledge and understanding without any specific application intended.

Applied research
Applied research is also work whose purpose is to attain new knowledge. However, it is directly primarily towards specific practical objectives or uses.

Development work
Development work is systematic work that uses existing knowledge obtained through research and/or experience for the purpose of achieving new or significantly improved materials, products, processes or services.

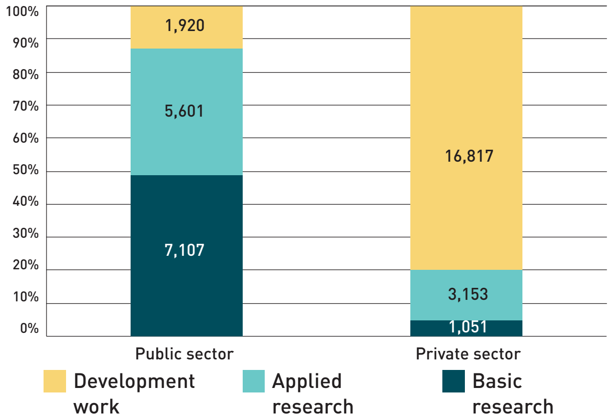
Figure 3: R&D as a percentage of GDP by sector, 2001



Source: OECD - Main Science and Technology Indicators 2002:2.

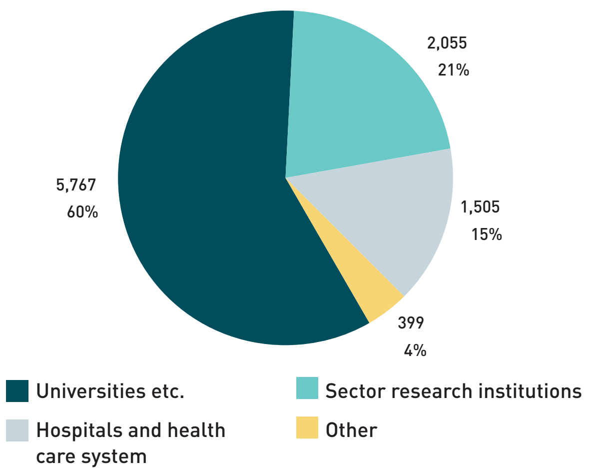
Note: Exceptions to 2001 as reference year: EU, OECD, Netherlands and Japan: 2000; Sweden: 1999.

Figure 4: R&D broken down by type, based on man-years in R&D, 1999



Source: Offentlig forskningsstatistik (Public sector research statistics) 1999; Erhvervslivets forskningsstatistik (Private sector research statistics) 1999.

Figure 5: Public R&D investment by sector, 2000



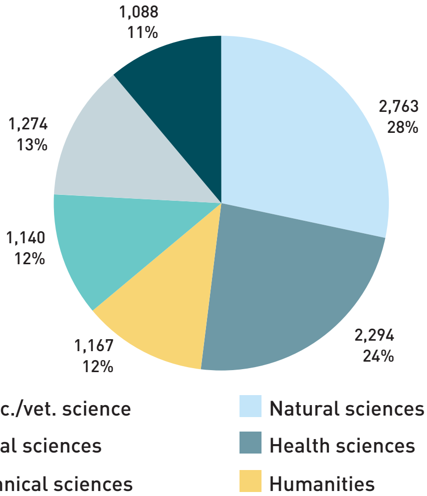
Source: Offentlig forskningsstatistik (Public sector research statistics) 2000.

In 2000, the government research institutes carried out 21 per cent of the public sector's R&D (DKK 2.1 billion).

Of the major scientific categories, the public sector invests most heavily in natural sciences. In 2000, DKK 2.8 billion, or 28 per cent of total public R&D investment, was invested in natural sciences (see figure 6). The second-largest area was health sciences, which accounted for 24 per cent of total public R&D investment (DKK 2.3 billion).

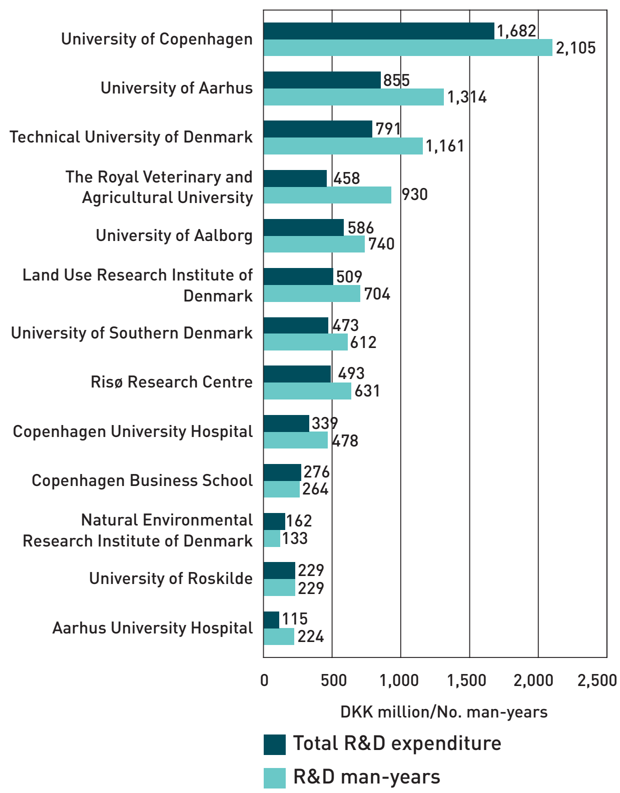
As shown in figure 7, the University of Copenhagen was the country's largest research institution, with more than 2,000 R&D man-years. Danmarks Jordbrugforskning (the Danish Institute of Agricultural Sciences) is Denmark's largest government research institute, with 704 R&D man-years.

Figure 6: Public R&D investment by research field, 2000 (DKK million)



Source: Offentlig forskningsstatistik (Public sector research statistics) 2000.

Figure 7: Denmark's largest public research institutions, 2001



Source: Offentlig forskningsstatistik (Public sector research statistics) 2000; Steering Committee of the Danish Government Research Institutes - Danske sektorforskningsinstitutioner (Danish Government Research Institutes) 2001/2002; the Danish Institute for Studies in Research and Research Policy - Forskning og udviklingsarbejde i sundhedssektoren - forskningsstatistik (Research and development work in the health care sector - research statistics) 2000.

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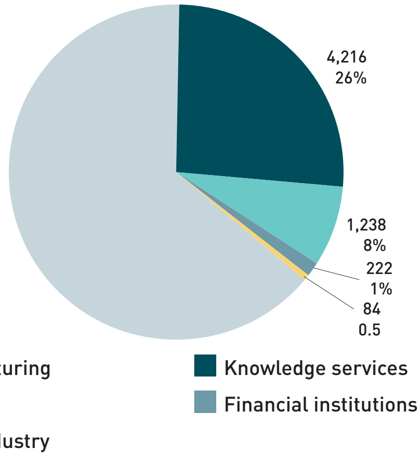
In 1999, the manufacturing industry accounted for the largest share of total R&D investment by the private sector, with a total of DKK 10.3 billion, equal to 64 per cent of the total (see figure 8). The second-largest sector was "knowledge services", which include the Authorised Technological Service Institutes (GTS institutes). This sector accounted for one-fourth of total business and industry R&D investment.

How is research and development work financed?

Most of the public funds for R&D are appropriations in the public Budget. In the public Budget for 2002, DKK 9.2 billion was allocated to R&D, nearly DKK 425 million less than in 1999, when the public Budget appropriations for R&D reached their highest level in the period 1994-2002 (see figure 9).

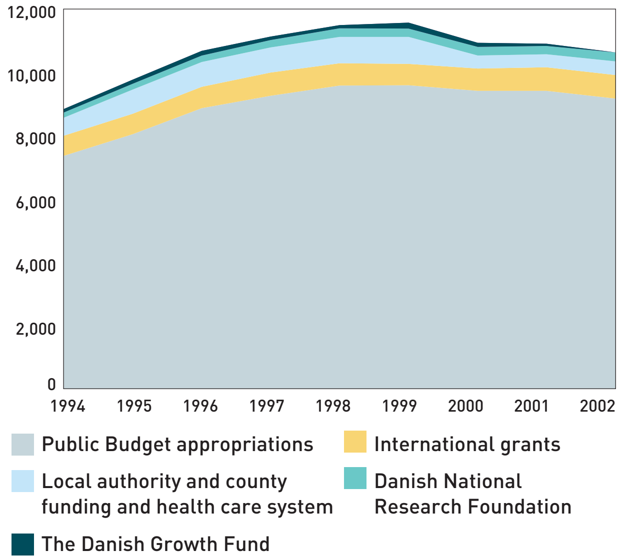
In the gathering of statistics on research in business and industry, the classical approach based on the broad scientific areas is not used. Instead, data is gathered on the basis of the companies' industry affiliation or classification, which extends across the primary scientific categories.

Figure 8: Private sector R&D investment by primary industry, 1999 (DKK million)



Source: Erhvervslivets forskningsstatistik (Private sector research statistics) 1999.

Figure 9: Public funding for R&D by source, 1994-2002, 2002 prices (DKK million)

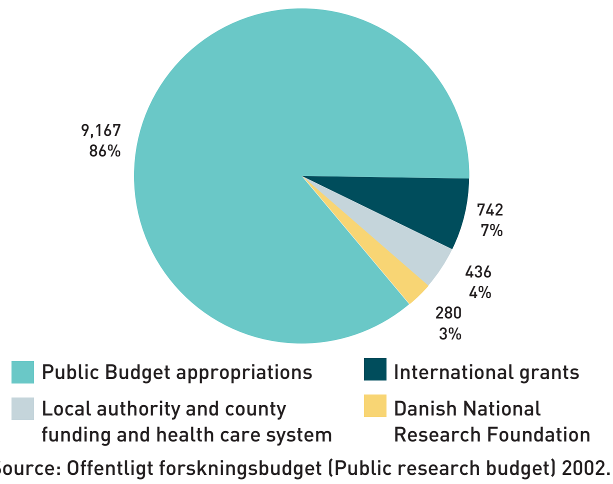


Source: Offentligt forskningsbudget (Public research budget) 2002.

Total public appropriations for R&D in 2002 amounted to DKK 10.6 billion, according to the public research budget for 2002.

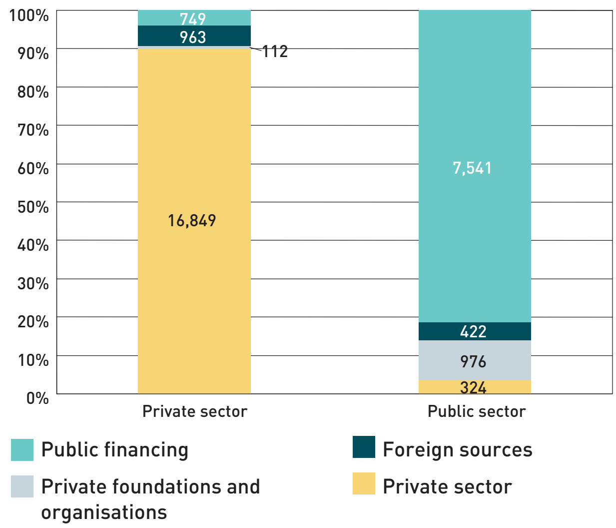
Business and industry financed 90 per cent of its own R&D activities in 1999 (see figure 11). In the public sector, the share of self-financing was 81 per cent. In 1999, the private sector financed 3.5 per cent of the public sector's investment in R&D, while the public sector financed 4 per cent of the private sector's R&D.

Figure 10: Public grants for R&D in Denmark, 2002 (DKK million)



Source: Offentligt forskningsbudget (Public research budget) 2002.

Figure 11: Financing of public and private R&D expenditure by sector and primary area, 1999 (DKK million)



Source: Forskningsstatistikken (Research statistics) 1999.

Figure 12 shows an outline of who financed total R&D work in Denmark in 1999. The chart shows that public funds financed 87 per cent of R&D at universities, while the private sector financed nearly 8 per cent of the universities' R&D.

Foreign funds financed approximately 6 per cent of the private sector's R&D, while the public sector contributed funds equal to 4 per cent to the private sector's R&D investment.

Research personnel

The source from which Denmark must obtain the results of R&D work is the persons who are occupied in R&D in both the public and private sectors. The calculations of human resources in R&D in Denmark are made on the basis of R&D personnel and the number of R&D man-years respectively. R&D personnel is defined as the total number of persons who are occupied wholly or partially with R&D work. R&D man-years is a converted figure for the number of full-time employees who work in R&D. We use both calculations because researchers employed at universities, for example, use a large amount of their time teaching students and this time is not included in the number of R&D man-years.

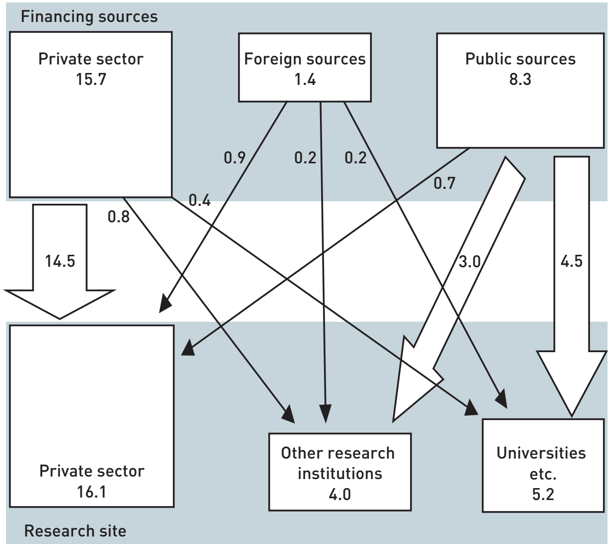
The trend in total R&D personnel and man-years (in both the public and private sectors) shows that the total R&D personnel increased by 20 per cent in the period 1993-2000. The number of man-years rose 28 per cent in the same period (see figure 13). However, the growth in the number of persons and man-years declined in recent years. Total R&D employees in 2000 amounted to nearly 2 per cent of the total labour force in Denmark. Of this group, 54 per cent worked in the private sector and 27 per cent worked at universities.

Academic Personnel and Technical Administrative Personnel

Academic personnel (AP) are persons employed in one of the job categories for academic personnel or persons with a Candidatus degree (Master degree).

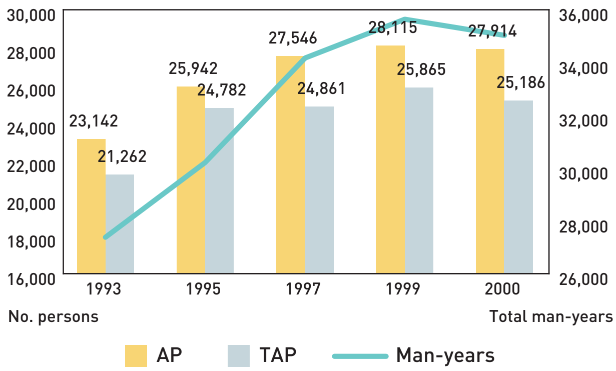
Technical administrative personnel (TAP) are all persons of any educational background who are not employed in a job category for academic personnel but who contribute to the research process.

Figure 12: The Danish research system: where financing comes from and where it goes, 1999 (DKK billion)



Source: Forskningsstatistikken (Research statistics) 1999.

Figure 13: R&D staff broken down by AP and TAP and trend in total man-years, 1993-2000



Source: Offentlig forskningsstatistik (Public sector research statistics) 2000.

Table 1: R&D employees by sector, 2000

	No. persons, 2000	% of total labour force
Private sector*	28,689	1.00%
Universities, etc.	14,244	0.50%
Other public sector	10,167	0.35%
Total	53,100	1.85%

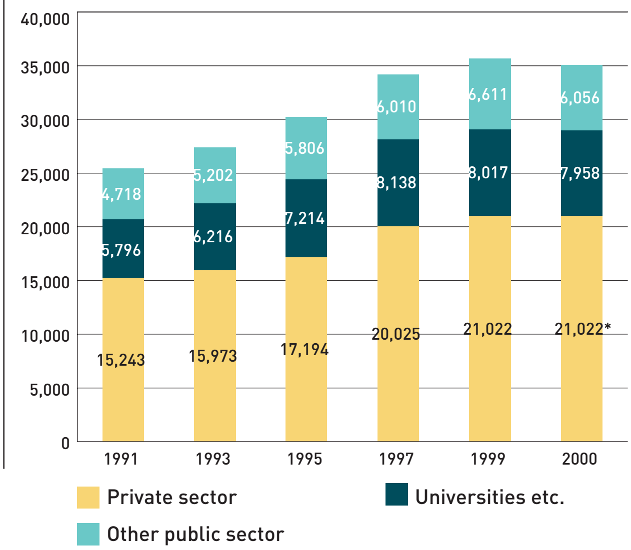
Source: Offentlig Forskningsstatistik 2000 (Public sector research statistics), 2000.

* Since there are no figures for R&D in the private sector in 2000, figures for 1999 are used.

The growth in the number of man-years from 1991 to 2000 took place mainly at universities and in business and industry. In business and industry in 2000, there were 21,022 man-years, or 60 per cent of the total number of R&D man-years (see figure 14).

Denmark ranks above the EU average in the percentage of R&D man-years in the total labour force, but under the levels in Sweden and Finland (see figure 15).

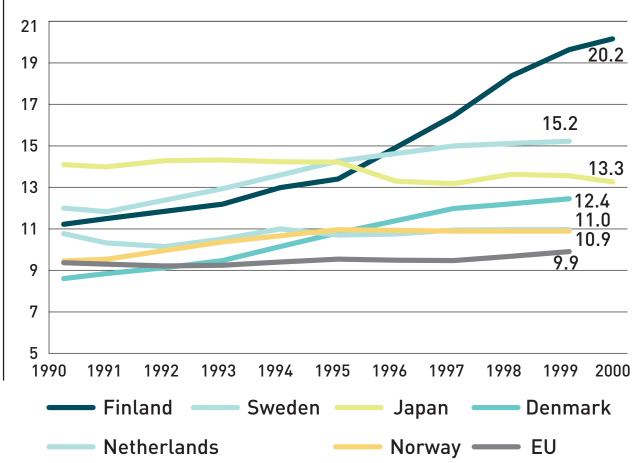
Figure 14: Man-years in R&D by sector, 1991-2000



Source: Offentlig forskningsstatistik (Public sector research statistics) 2000.

* Since there are no detailed statistics on private sector R&D for 2000, 1999 figures were used.

Figure 15: R&D staff per 1,000 in labour force, 1990-2000



Source: OECD, Main Science and Technology Indicators, 2002:1.

Academic personnel (AP) at universities accounted for 36 per cent of the total academic personnel in Denmark in 2000 (see table 2).

In 2000, associate professors, at 41 per cent, accounted for the largest share of academic personnel at the universities, while professors accounted for nearly 10 per cent of academic personnel (see figure 16).

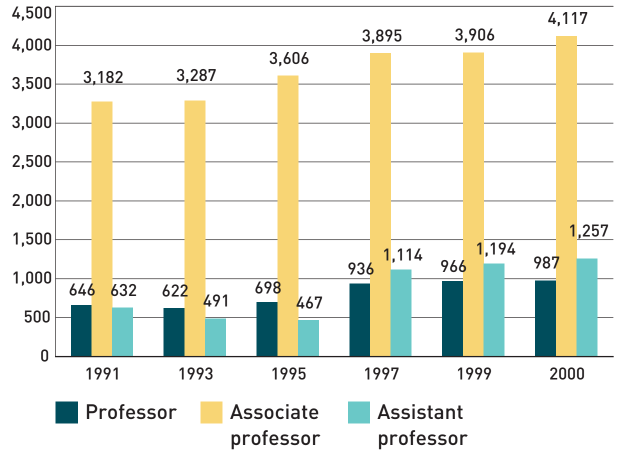
The number of professors rose from 646 in 1991 to 987 in 2000, equal to an increase of 53 per cent. The number of assistant professors has risen nearly 100 per cent since 1991.

Table 2: Academic personnel by sector, 2000

	No. persons, 2000	% of total AP
Universities, etc.	10,057	36.03%
Other public sector	6,566	23.52%
Private sector	11,292	40.45%
Total	27,915	100.00%

Source: Offentlig Forskningsstatistik 2000 (Public sector research statistics), 2000.

Figure 16: Academic personnel at universities etc., 1991-2000



Source: Offentlig forskningsstatistik (Public sector research statistics) 1991-2000.

Close connection between national scientific and economic specialisation >

Name: Keld Laursen
Position: Associate Professor at Copenhagen Business School and researcher at Centre for Economic and Business Research (CEBR)

Karl Marx started a fundamental debate on the connection between the economic and the scientific systems, which is still going on today. There have been arguments stating that developments within the scientific system generally take place independently of the economic system, and some stating that considerable potential exists for utilising the scientific system to shape the economic sphere.

This connection between economic specialisation, measured as production specialisation, and relevant scientific specialisation is analysed in Laursen and Salter (2002) for 17 OECD countries between 1981 and 1994. The study covers 17 production industries.

Scientific knowledge and industry

The connection between economic and scientific specialisation has been analysed by coupling scientific knowledge with the industries in which this knowledge is applied. The coupling is based on the publications of private British companies in scientific journals.

The assumptions of the coupling is that if companies in certain industries publish (many articles) within a specific scientific field, this scientific field is also relevant for that industry. This means that if a country's researchers publish many articles within a certain scientific field and this field is also relevant for a certain industry, the scientific knowledge base will, other things being equal, be high for that industry.

The study shows that there is a slim connection between scientific strength and economic specialisation for the majority of the industries which can be described as knowledge-based (e.g. the pharmaceutical and electronic industries) as well as for several large-scale industries (e.g. the manufacture of means of transport). Overall, a connection is found in 10 out of a total of 17 industries.

In other words, the results suggest that scientific systems in the OECD countries, to a great extent, are influenced by industrial and social needs.

Companies publish a broad variety of articles

Furthermore, the study shows that companies in practically all industries publish within many different scientific fields. For example, companies that produce industrial chemicals publish within no less than 75 out of 77 possible scientific fields.

Other industries publish within fewer fields, but none publish within fewer than approximately 20 scientific fields. This observation indicates a considerable challenge for political initiatives which are intended to support innovation within a certain industry by investing in a limited number of scientific fields.

You can read more here:

www.cbs.dk/departments/ivs/laursen

Laursen, K. and Salter, A. (2002), The Fruits of Intellectual Production: Economic and scientific specialisation among OECD countries, DRUID Working Paper No. 02-03, Copenhagen, IVS; Copenhagen Business School.

Results of research

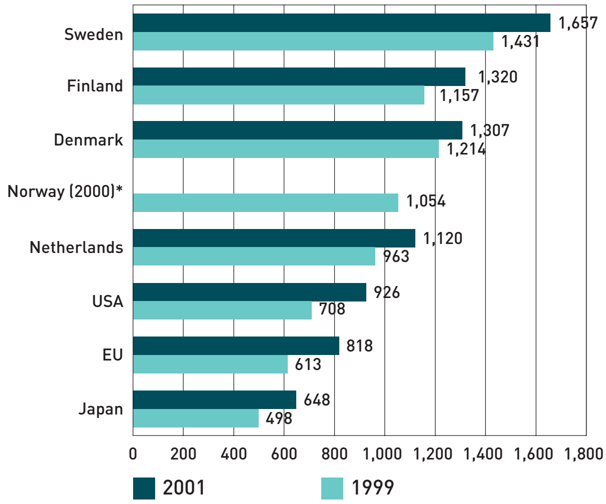
One of the common indicators of the results of research is the number of scholarly publications. The number of scholarly publications gives an indication of the extent of research activity that is taking place. A derivative indicator is the number of times scholarly publications are cited by other researchers in their R&D work. This gives an indication of the power of penetration of the published research.

A later and more derivative indicator of research results is found by measuring the number of patents undertaken on the basis of new scientific breakthroughs that come from R&D work. We examine this more closely in the section on innovation.

Scholarly publications

Figure 18 shows the number of scholarly publications per 1 million inhabitants in 1999 and 2001. It shows that Denmark ranks high among the leading nations according to publication activity. It is also evident that Denmark stands significantly above the average for the EU and most of the other countries with which it normally compares itself.

Figure 17: Number of scholarly publications per million inhabitants, 1999/2001



Source: European Commission: Key Figures 2001, 2002.

*: National Science Indicators/Institute for Scientific Information, ISI. Reproduced in NIFU 2001.

The following types of publications are contained in the National Science Indicators (NSI) database of the Institute for Scientific Information (ISI): scholarly articles, reviews, research notes, working papers and follow-up scholarly work on the basis of previously published material. The collective designation in this report is "publications", which covers similar general designations such as "papers".

>

Citations

Denmark's share of the total issuance of scholarly publications in the world in the period 1993-99 rose by approximately 12 per cent (see figure 18).

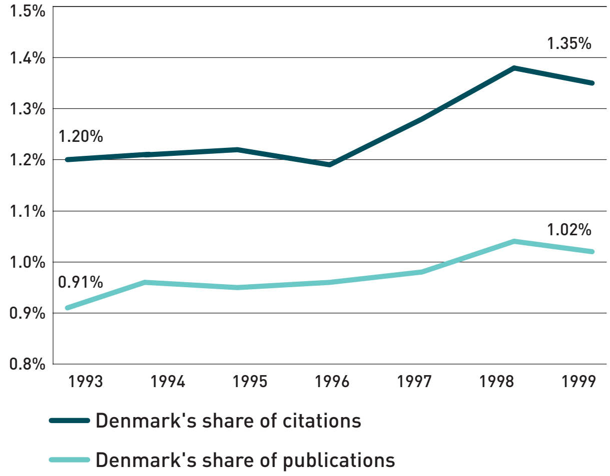
The increase in activity occurred at the same time that the quality remained very high, as the rise in publications was followed by a rise in the number of citations.

Impact factor

Research quality can also be evaluated according to the so-called "citation impact factor", which is a measure of the power of penetration of research. The number of citations gives an indication of the quality of scholarly publications.

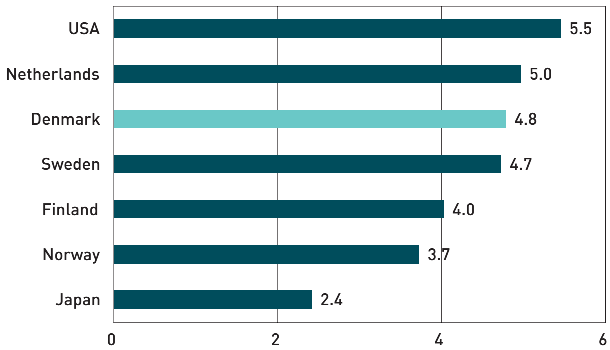
With an average 4.8 citations per scholarly publication, Denmark ranks very close to the top of the list of OECD countries (see figure 19).

Figure 18: Denmark's share of the world's total citations and scholarly publications, 1993-1999



Source: National Science Indicators/Institute for Scientific Information, ISI.

Figure 19: Selected OECD countries' total impact factor, 1995-1999



Source: National Science Indicators/Institute for Scientific Information, ISI.

Impact factor

This indicator is an expression of the relation between the number of citations to the number of scholarly publications in a given country. Example: Denmark's impact factor in the period 1995-99 is 4.8, determined on the basis of 166,993 citations /34,887 scholarly publications = 4.8.

3.2 University educational programmes >

- In 2001, total appropriations for universities reached nearly DKK 10 billion.
- Today more than half of the students in a given year begin a higher educational programme of short, medium or long duration, compared with less than one-third in 1980. Approximately 18 per cent begin a university education.
- In 2000, the number of university students exceeded 100,000.
- In recent years, approximately 18,000 students have begun university annually, with most (70 per cent) studying social sciences and humanities. These two groups account for 60 per cent of the Candidatus (Master programme) graduates.
- In 2000, there were 8,592 graduating Candidatus students, and the number of graduates has risen steadily since 1980.
- The number of PhDs has more than doubled during the past 10 years. However, in recent years the number of entering PhD candidates has been rather stable at about 1,100.
- Half of all PhD degrees in 2000 were awarded in health sciences and natural sciences.
- An increasing number of people obtain Master degrees in the adult education system.

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Investment in education

In an international perspective, Denmark has the highest total expenditure for education of any country. Of the total expenditure for the educational system, however, only about 20 per cent is spend on higher education, while the countries that spend the most on this segment invest 25-30 per cent. Table 1 shows that the total investment in higher education in Denmark amounts to about 1.5 per cent of GDP. This is approximately the same level as in the other Nordic countries.

The calculation includes direct appropriations for educational programmes and appropriations for support functions. For universities, research appropriations are also included. On the other hand, the figure does not include the State Education Fund (SU), which is used for student grants.

The appropriations for universities rose nearly DKK 500 million from 1997 to 2001, or 5 per cent. As figure 1 shows, the increase took place in research (DKK 248 million) and ordinary education (DKK 280 million).

In 2001, research appropriations for universities amounted to DKK 3.3 billion, or 33.3 per cent of total university appropriations, while DKK 3 billion, or 31 per cent, went to ordinary educational programmes.

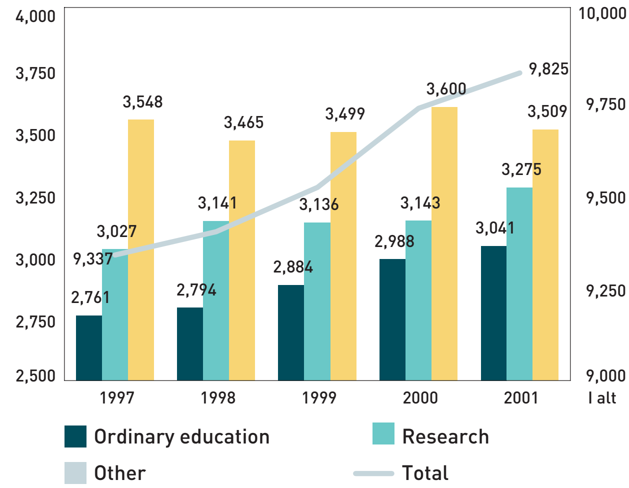
Table 1: Investment in higher education as a percentage of GDP (1998)

	Higher education	
	Public	Private
Denmark	1.49	0.04
Finland	1.68	-
Netherlands	1.15	0.03
Norway	1.42	0.09
Sweden	1.49	0.17
Average*	1.06	0.29

Source: Education at a Glance, 2002.

* Mean value for all countries in OECD's calculations.

Figure 1: University appropriations, 1997-2001, 2003 prices* (DKK million)



Source: Finanslovforslag (Public budget proposal) 2003.

* The figures exclude grants to the Danish University of Education, grants for capital expenditure and the operating income that the universities obtain by selling services on market terms.

>

Appropriations for education are correlated to output, measured as the number of student man-years that universities produce. As table 2 shows, there has been a large rise both in appropriations for education and in activity. The table also shows that unit costs per student man-year fell steadily throughout the period, from DKK 50,778 to DKK 49,838, or nearly 2 per cent.

There are three categories of education appropriations. Appropriations for *ordinary education* are made for instruction in Bachelor and Candidatus programmes; appropriations for *exchange students* are made to support internationalisation, and appropriations for *open education* are made for instruction that is offered as continuing education and further education (for example Master programmes).

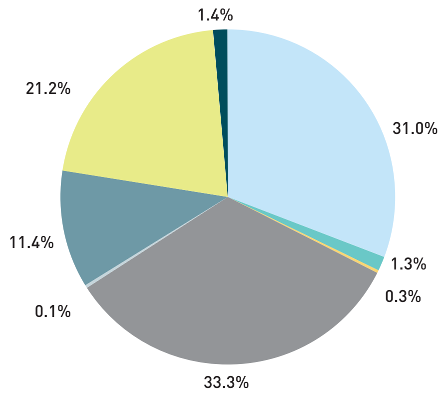
Basic appropriations for *research* are made for research expenses, including expenses for the training of researchers. Besides this type of research appropriation, universities also receive funds to finance the *grant-financed research activity*. These funds come from research councils, the EU, private donors and others.

Appropriations for *other purposes* are made for expenses for support functions and special obligations such as libraries, museums, collections, gardens and so on.

In addition, the universities receive *basic appropriations* per institution.

Finally, a smaller portion of university activity is financed by *other grants* such as EU grants for educational programmes etc.

Figure 2: University appropriations, 2001*



Source: Finanslovforslag (Public budget proposal) 2003.

* The figures exclude grants to the Danish University of Education, grants for capital expenditure and the operating income that the universities obtain by selling services on market terms.

Table 2: Appropriations, activity and unit cost for ordinary educational programmes at universities

2003 prices	1997	1998	1999	2000	2001
Appropriations (DKK million)	2,761,453	2,793,638	2,883,530	2,988,029	3,041,000
Student man-years	54,383	55,449	56,952	59,803	61,017
Unit cost (DKK)	50,778	50,382	50,631	49,965	49,838

Source: Public budget, 2003.

As figure 3 shows, the number of men and women with Candidatus degrees (Master degrees) rose sharply in the period 1993-99. The number of women with Candidatus degrees rose about 45 per cent, and the number of men rose 17 per cent. The total share of the population with Candidatus degrees rose from 3.8 per cent in 1993 to 4.8 per cent in 1999. This is an increase of 25 per cent.

Enrolment in higher education

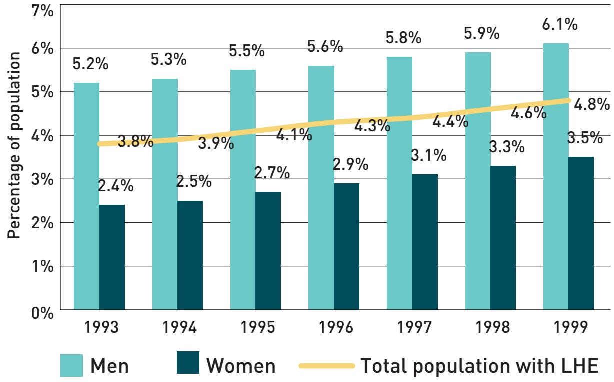
The number of students in higher educational programmes in Denmark has risen sharply in the past 20 years. In 1980, there were nearly 117,000 students in such programmes, and in 2002 there were about 202,000. About 105,000 of these were enrolled in research-based programmes at universities (Bachelor, Candidatus and PhD), 22,000 were enrolled in short-cycle programmes, and 75,000 were enrolled in medium-cycle programmes. The total growth for higher educational programmes was thus almost 73 per cent during the period, equivalent to an annual growth of 3.8 per cent.

Of the adult population, 27 per cent has completed a course of higher education, compared with the OECD average of 23 per cent. However, short- and medium-cycle higher educational programmes are also included in this figure. The 18 per cent of young students who begin a university education, is slightly below the OECD average.

More than half of the individuals in a given year who reached university age in 2000, began a short-, medium- or university degree (Master or PhD) programme.

In the beginning of the 1980s, only approximately 30 per cent of young people began a higher educational programme, and only about 8 per cent began a university education. In 2000, the corresponding figures were 52 per cent and 18 per cent. Thus the percentage enrolled in university degrees (Masster or PhD) programmes has been stable during the period. In absolute figures, an increasing number of young people pursue a higher education despite the decrease in the youth population in recent years.

Figure 3: Share of population with a university degree by sex, 1993-1999



Source: Ministry of Education 2001: Uddannelse på kryds og tværs (Education almanac).

University programmes

Bachelor programmes	Three-year, medium-cycle higher educational programme that qualifies the recipient for admission to a Candidatus degree programme.
Candidatus degree programme	University degree (Master or PhD) programme concluding with a thesis (equivalent to a Master programme). Qualifies the recipient for admission to a PhD programme.
PhD programme	The highest degree granted in the educational system, a supplement to the Candidatus degree programme.

Basis for recruiting

The basis for recruiting students to higher educational programmes has been strengthened through post-compulsory education.

Since the beginning of the 1980s, the percentage of students who complete post-compulsory education has risen from 72 per cent to 83 per cent. The percentage of students attending upper-secondary schools rose sharply in the 1980s, but in recent years the balance between upper secondary school enrolment and vocational educational programmes has stabilised. More than half now complete an upper secondary education, while 31 per cent completes a vocational programme. Although higher educational programmes recruit primarily from upper secondary schools (consisting of upper secondary schools; the higher preparatory examination; the higher commercial education and higher technical examination), 15 per cent of students in vocational programmes continue in higher educational programmes such as the engineering diploma programme and technical short-cycle higher educational programmes. Of students in the social sciences and health sciences, 10 per cent continue in nursing programmes.

Altogether, the universities have seen a large rise in enrolment. Enrolment in Bachelor programmes began to rise significantly after 1993. Before that time, only the Bachelor of science and Bachelor of commerce degrees were counted as Bachelor degrees.

The number of PhD students in the same period rose 43 per cent.

In 2000, enrolment in research-based educational programmes at universities totalled 105,417. Figure 4 shows that Candidatus degree students numbered slightly over 53,000 (51 per cent) of total enrolment, students in Bachelor programmes numbered approximately 47,000 (45 per cent), and PhD students numbered approximately 5,000 (5 per cent).

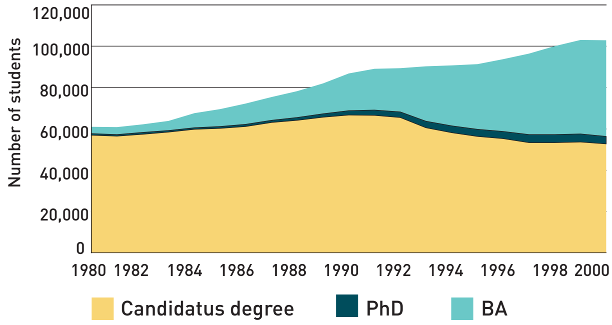
Admission to universities

Since 1995, the annual number of students who begin university programmes has been rather stable at approximately 18,000. Figure 5 shows the number of new students broken down by faculty in 2002. The distribution by faculty has been fairly stable since 1995.

Social sciences and humanities students make up about 70 per cent of total university students.

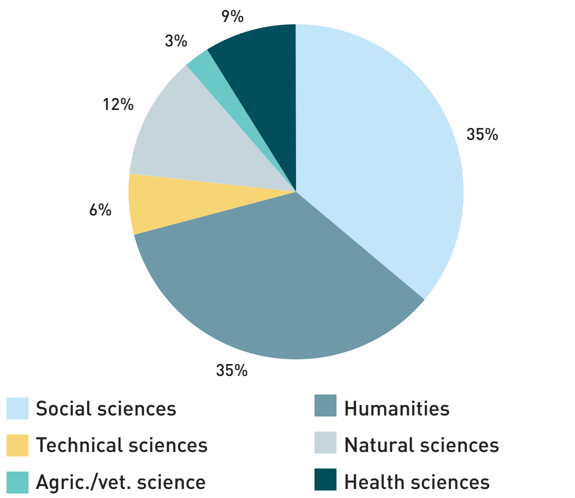
Figure 6 shows that 29 per cent of new students in 2001 attended the University of Copenhagen. Together with the University of Aarhus and the University of Southern Denmark, admissions to the three largest universities accounted for more than half of total new enrolment. Copenhagen Business School's new enrolment was at the same level as at the University of Southern Denmark and the Aalborg University.

Figure 4: Number of persons in university based programmes, 1980-2000



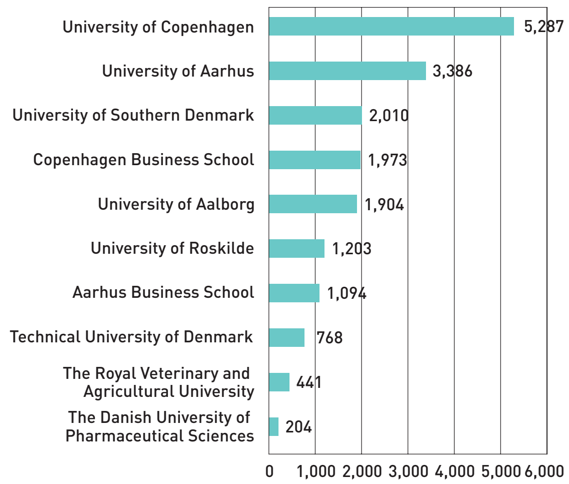
Source: Ministry of Education and Ministry of Science, Technology and Innovation.

Figure 5: Entering university students by faculty, 2002



Source: Den Koordinerede Tilmelding (The Coordinated Registration System) 2002.

Figure 6: Entering university students by institution, 2001



Source: Den Koordinerede Tilmelding (The Coordinated Registration System) 2002.

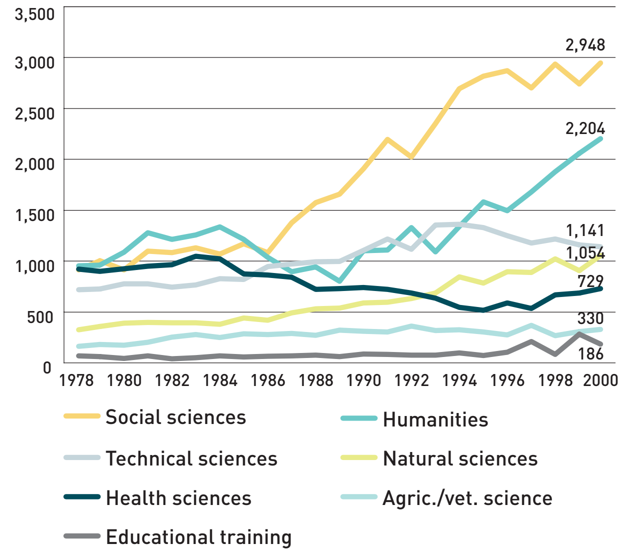
Graduation
Overall, students in the social sciences and humanities accounted for more than 60 per cent of all students who obtained Candidatus degrees in 2000.

The nearly 3,000 social sciences students represented about one-third of total graduates with a university degree (Master or PhD). Humanists numbered 2,200 graduates, or about 25 per cent of total graduates in 2000.

The technical sciences (especially Master programmes in engineering) declined sharply in enrolment in the 1990s, but they are presently on the way up again. Enrolment in natural sciences has risen slightly. However, altogether enrolment in technical sciences, natural sciences and agricultural sciences declined substantially in the 1990s, however. Enrolment in the health sciences dropped most of all, but it is now rising again (see figure 7).

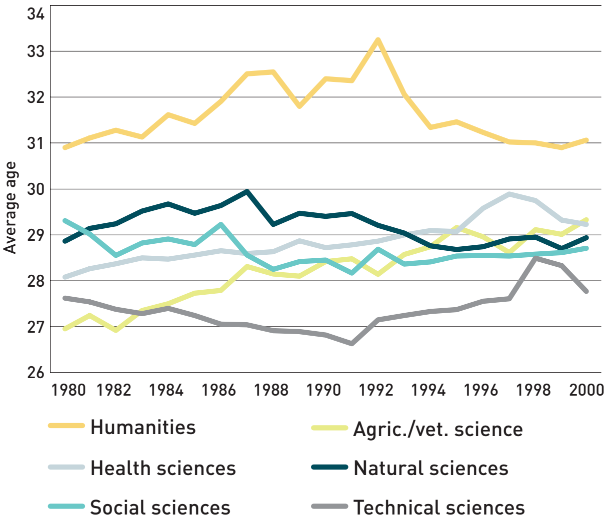
During the past 20 years, the average age of humanities graduates has been much higher than that in the other faculties, and it is the only faculty whose average graduation age is over 30. As shown in figure 8, the average graduation age in the other faculties since 1987 has fluctuated between 28 and 30, with the exception of technical sciences, which had an average graduating age of about 27 during most of the period.

Figure 7: Number of graduates by faculty, 1978-2000



Source: Statistics Denmark, Ministry of Education and Ministry of Science, Technology and Innovation.

Figure 8: Average age of university graduates by faculty, 1980-2000



Source: Statistics Denmark, Ministry of Education and Ministry of Science, Technology and Innovation.

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The transition from the Candidatus degree programme to the PhD level

In terms of the number of students who continue in PhD programmes after completing a Candidatus degree programme, the health sciences, technical sciences and agricultural sciences are dominant, accounting collectively for 77 per cent (see figure 9).

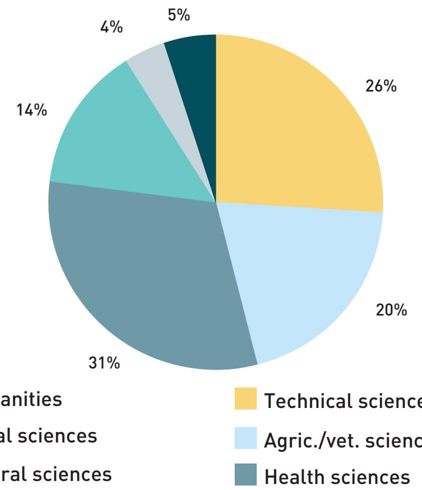
Technical and natural sciences are much stronger at the PhD level than at the Bachelor and Candidatus degree levels. While the percentage of students who continue in PhD programmes in health sciences, natural sciences and technical sciences is more than 30 per cent, the corresponding figures for the humanities and social sciences are below 5 per cent.

PhD students

As figure 10 shows, there was a substantial increase in the number of PhDs over the period.

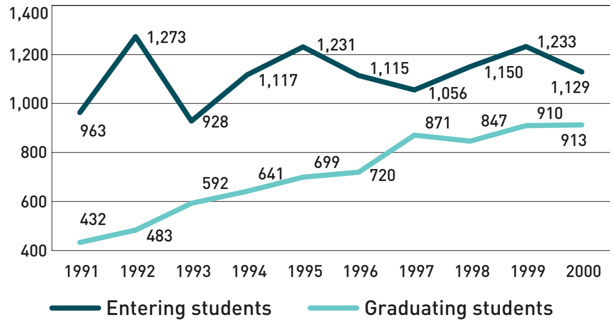
In 2000, the health sciences and natural sciences together accounted for half of all PhDs awarded, with health sciences representing 27 per cent and natural sciences 23 per cent.

Figure 9: Entering PhD candidates by faculty, 2000



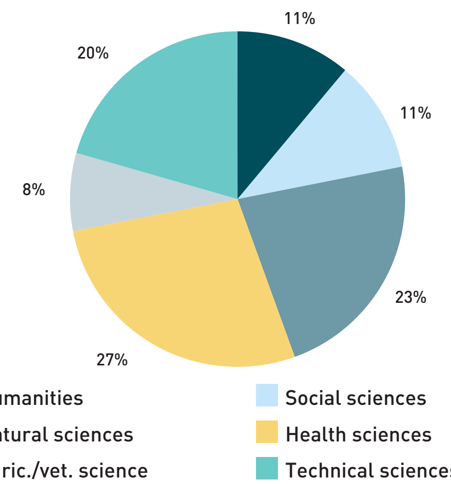
Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

Figure 10: Entering and graduating PhD students, 1991-2000



Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

Figure 11: PhDs awarded, by faculty, 2000



Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

Figure 12 illustrates the individual institutions' shares of PhDs awarded. The University of Copenhagen represented the largest share, with about one-third of the total. The University of Aarhus ranked second, with about one-fifth. The Greater Copenhagen region accounted for 60 per cent of all PhDs awarded in 2000.

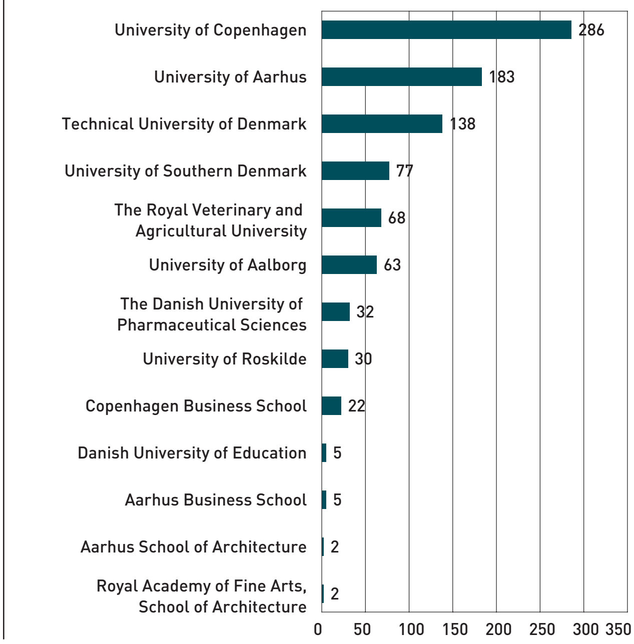
In 1999, there were 449 foreign PhD students enrolled in Denmark, equal to 9 per cent of the total of 5,035. At the same time, there were 247 Danish PhD students studying abroad (see figure 13).

For the higher educational programmes as a whole, Denmark is a net exporter of students.

2.6 per cent of students in Denmark are foreign, while the number of Danish students abroad equals 3.1 per cent of the total number of students in higher educational programmes in Denmark. Sweden and Norway, among others, send more students abroad (OECD: Education at a Glance 2002).

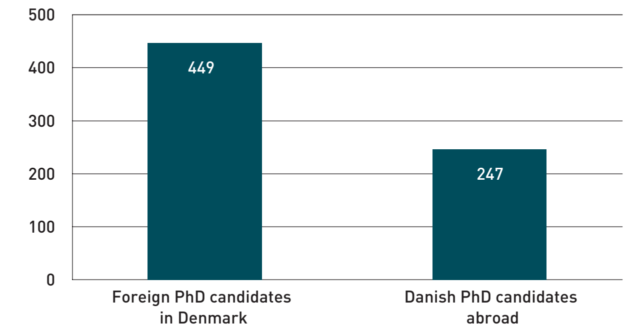
In absolute figures, an increasing number of Danish students study abroad. From 1995 to 2001, the number of outgoing exchange students grew from about 3,400 to 4,300, while the number of Danish students who took their education grants outside the country for a complete course of study rose from about 2,000 to 4,400 from 1992 to 2000.

Figure 12: PhDs awarded by institution, 2000



Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

Figure 13: PhD candidates, 1999



Source: Data om dansk forskeruddannelse (Data on Danish research training programmes), 2001.

According to the calculations of the Ministry of Science, Technology and Innovation, there is a risk of a long-term shortage of several thousand Candidatus graduates and PhDs in the technical sciences and natural sciences in 2010 and 2020. In the shorter term, however, the market is saturated. All groups of new graduates of Candidatus degree programmes are experiencing increasing unemployment at present. Only the health sciences have the prospect of a shortage in the near future. As early as next year, however, Denmark will begin to see a generation-shift that will hit the technical and natural sciences areas especially hard.

Job mobility creates a potential for innovation

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Name: Ebbe Krogh Graversen
Position: Research Director, the Danish Institute for Studies in Research and Research Policy

The physical job mobility among research-competent or highly educated employees is a visible and measurable indicator of the diffusion, circulation and accumulation of knowledge in the national innovation system.

Mobility secures access to competencies

Knowledge accumulation and diffusion are fundamental mechanisms in new frameworks for economic growth. The higher the knowledge level of society is, the better society can innovate and implement innovations.

Mobility among highly education employees provides companies with the ability to possess competencies at the right time to ensure higher growth and better finances. Thus, the physical mobility of research-competent employees has a direct influence on the economy.

Furthermore, a stable job mobility between companies and knowledge institutions furthers the spread of new knowledge and increases utilisation of this knowledge among employees, thus resulting in potential financial growth.

High mobility in Denmark

Graversen, et al. (2002a) find that 26 per cent of highly educated employees in Denmark are new at the workplace compared to the previous year. Of these, 20 per cent come from other jobs and can be directly considered to be "knowledge transferers". Correspondingly high mobility rates are found in the other Nordic countries.

The high mobility rates for Nordic countries mentioned above, are based on national records data. If data from Eurostat's Labour Force Surveys (LFS) is used, substantially lower job mobility rates are found. Based on these data, the Nordic countries are not systematically different from other EU or OECD countries with regard to the rate of mobility.

If one looks at the share of mobility among employees with research competencies, Graversen (2001) shows that it is at the same level as that of the rest of the Danish population. Mobility among publicly employed researchers is slightly higher. However, the mobility of researchers between public research institutions and private companies is, low although still significant, cf. Graversen (2002b). In this area, there are grounds for increasing the exchange of knowledge and companies' knowledge levels via job mobility as a way of utilising a growth potential.

The relatively high job mobility in Denmark suggests a considerable spread in knowledge that underpins the great innovation potential which exists in a national innovation system with an excellent knowledge-based infrastructure.

You can read more here:

www.afsk.au.dk/pers_pages/eg.htm

Graversen, E.K., Nås, S.O., Ekeland, A., Bugge, M., Svanfeldt, C. and Åkerblom, M. (2002a). *Knowledge transfer by labour mobility in the Nordic countries*. AFSK WP 2002/1.

Graversen, E.K. (2002b). *Forskermobilitet (Researcher mobility)*. AFSK WP 2002/8.

Graversen, E.K. (2001). *Human Capital Mobility into and out of Research Sectors in the Nordic Countries*. Chapter 8 in the OECD Proceedings "Innovative People. Mobility of skilled Personnel in National Innovation Systems."

Candidatus (Master programme) graduates broken down by faculty

The balance between humanistic and social sciences Candidatus graduates on the one hand and technical and natural sciences graduates on the other can be elucidated both nationally and internationally.

Nationally, two large groups accounted for almost 60 per cent of Candidatus graduates in 2000. They were social sciences and humanities. In the past 20 years, the percentage of social sciences Candidatus graduates has risen steadily, and in 2000 one-third of the total number of Candidatus graduates had a social sciences degree. Humanities graduates made up about 25 per cent of Candidatus graduates in 2000, about the same share as in 1980 but somewhat higher than in 1990.

Natural sciences graduates have increased in percentage since the 1980s. However, since 1994, the percentage has been stable. The technical sciences relapsed sharply in the 1990s. The same is true for agricultural and veterinary science.

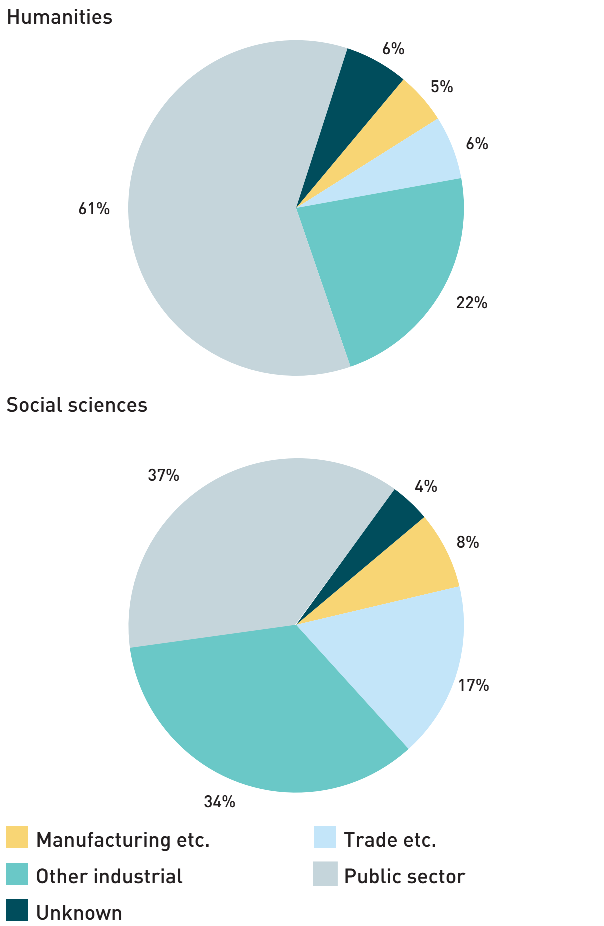
The largest drop has occurred in the health sciences. The level is still somewhat less than half of what it was in 1980. However, a turnaround began in the mid-1990s.

OECD calculations show that technical and natural sciences account for about 23 per cent of graduates in Denmark. In Germany, Sweden and Finland, the level is close to 30 per cent, while in the USA, Canada and the Netherlands, among other countries, the level is below 20 per cent.

As a percentage of the relevant age groups, Denmark's PhD graduates represent 1.1 per cent, while the OECD average is 1.0 per cent. In comparison, the figure stands at about 2 per cent in Sweden and Finland, and at 1.3 per cent in the USA.

An increasing number of PhDs both in Denmark and the OECD as a whole are employed outside the public sector, especially in the service sector. This corresponds to the trend described for Candidatus graduates.

Figure 14: Graduates' employment, 2000



Source: Statistics Denmark.

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Educational programmes and sectors

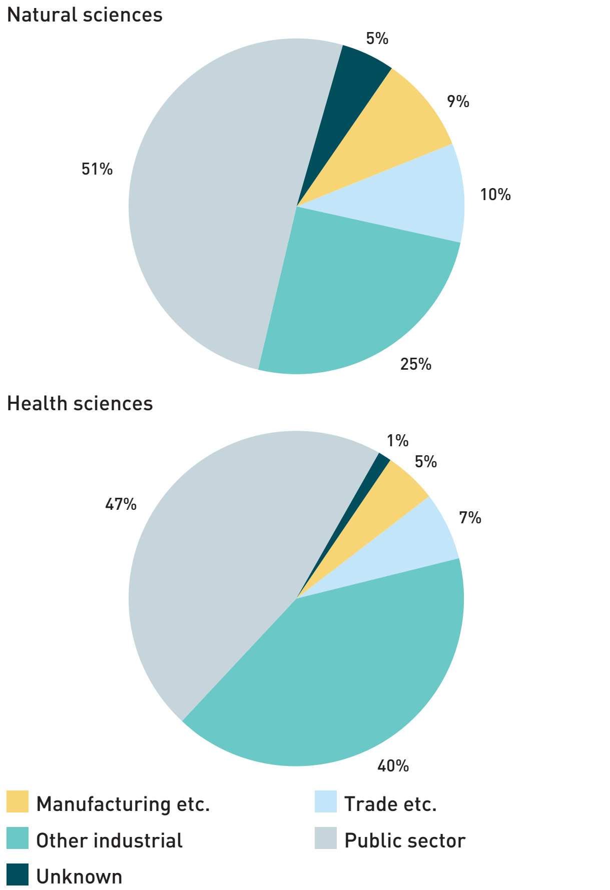
When one attempts to outline the sectors in which Candidatus graduates are employed, the various educational areas have diverse profiles. Through the 1990s there was a trend in several of the educational categories towards a shift away from the public labour market to the private sector, especially to the private service sector.

Slightly more than half of all humanities Candidatus graduates are public sector employees (see figure 14). The percentage declined about 5 percentage points during the 1990s, however. Thus, there is an increasing tendency for humanities Candidatus graduates, especially new graduates, to seek work in other sectors. The same trend is occurring with social sciences Candidatus graduates. In 1992, nearly 42 per cent were public employees, and in 2000, the level was mired at about 37 per cent.

For natural sciences Candidatus graduates, there was also a significant shift in sector distribution during the 1990s. Once again, there was a relative drop in the number of public employees, while the percentage of employees in other sectors, particularly in the trade and other services sectors, rose. The health sciences sector distribution has been very stable in recent years, and this is owing mainly to doctors' relatively poor opportunities for sector substitution. Health sciences educational programmes are still distinctly profession-programmes.

The technical sciences and agricultural and veterinary science Candidatus graduates are the groups with the lowest level of public employees. But here also there remains a trend away from the public to the private sector.

Figure 15: Graduates' employment, 2000



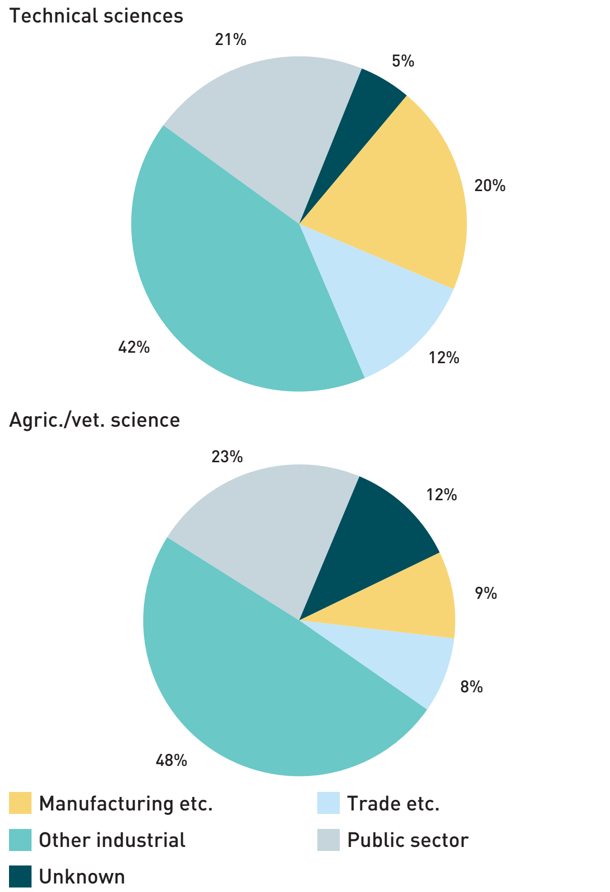
Source: Statistics Denmark.

In the public labour market, humanities and social sciences Candidatus graduates account for 55 per cent of all employees. The figures should be considered in light of the fact that humanities and social sciences Candidatus graduates represent 19 per cent and 31 per cent of the total Candidatus graduates, respectively.

Strong growth in adult education at the university level

In recent years, the higher educational system for adults has been expanded at all levels. This is also true for university educational programmes. Many of the new Master degrees qualify graduates for management and middle management positions in the public and private sectors. As table 3 shows, this activity has grown substantially year after year.

Figure 16: Graduates' employment, 2000



Source: Statistics Denmark.

Table 3: Overview of number of student-years per master's programme

	1999	2000	2001
Total master's programmes	369	505	685
Distribution:			
Social sciences master's programmes*	133	214	189
Health and social sciences master's programmes	71	92	88
Technical natural science master's programmes**	137	86	168
Humanistic-education master's programmes***	28	112	240

* Includes Master of Business Administration, Master of Public Administration, Master of Public Management, Master of Public Policy, Master in Management Development and others.

** Includes Master of IT, Master in Management of Technology, Master of Fire Prevention Technology and others.

*** Includes Master of Learning Processes, Master of Upper Secondary Education, Master of Educational IT, Master of Global e-Commerce, Master of Multimedia Arts and others.

Note: A student-year is defined as a student who has paid fortuition equivalent to one year's full-time study. Students normally study part-time for two years.

3.3 Innovation and networking

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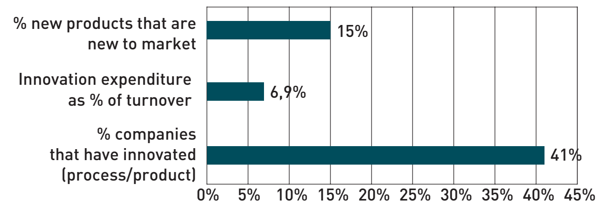
- 41 per cent of Danish companies innovated in the period 1998-2000.
- Investments in innovation represent 7 per cent of companies' turnover, while 15 per cent of companies' turnover derived from products that were new to the market.
- Of the companies that have innovated, 43 per cent have collaborated with the public sector or with private institutes or companies on innovation.
- 54 per cent of companies that conduct R&D, have collaborated with the public sector or with private institutes or companies on innovation.
- In 1999, 25 per cent of the companies that conducted R&D collaborated with public research institutions.
- In the period 1995-2000, almost 100,000 companies were founded in Denmark, of which one-third were in the knowledge-based service and high technology industries.
- With high technology products accounting for 20 per cent of exports, Denmark ranks in the middle segment of comparable countries.

Innovation activity in Danish business and industry

Figure 1 shows Danish companies' innovation activity. 41 per cent of Danish companies innovated in the period 1998-2000. The chart also shows that for companies that have innovated, the investments in innovation represent 7 per cent of turnover. Not all innovations carry the same amount of novelty value. In many cases, innovations concern minor, gradual changes in existing products or production processes. The chart shows that 15 per cent of the innovative businesses' turnover derived from products that were so new that they were also new for these companies' markets.

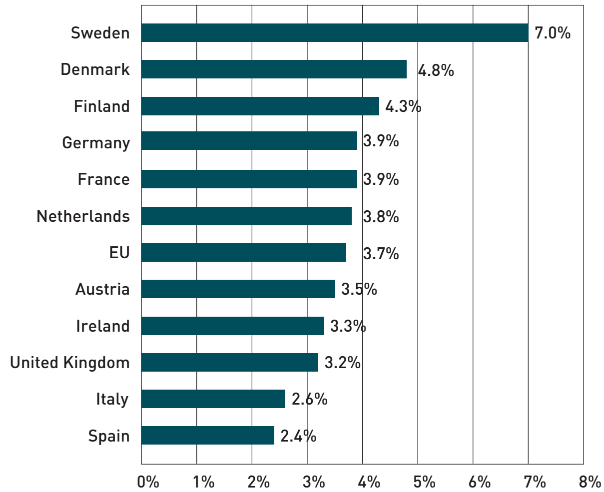
There are no present figures for Denmark's international position in actual innovation activity. The latest figures are from 1996. But on the basis of these figures, Denmark stands at the high end according to investment in innovation as a percentage of company turnover (for the manufacturing sector). In 1996, total investment in innovation amounted to nearly 5 per cent of Danish companies' turnover (see figure 2). This level was exceed only by Sweden, with 7 per cent, while the EU level was less than 4 per cent. On the other hand, it turned out that Danish companies developed significantly fewer new products that were also new to the companies' markets than companies in the countries with which Denmark normally compares itself. Most of the products were new only for the companies themselves.

Figure 1: Danish companies' innovative activities, 1998-2000



Source: Danish Institute for Studies in Research and Research Policy, Innovation study.

Figure 2: Investments in innovation as a percentage of turnover in the manufacturing sector, 1996



Source: Community Innovation Survey (CIS2) 1996, EU.

Innovation

Innovation includes both product and process innovation.

Product innovation.

A good or service is an innovative product if it is either new or significantly improved in its fundamental characteristics, technical specifications, built-in software, intangible components, applications or user-friendliness.

Process innovation.

A process is innovative when the result is new or significantly improved production technology, concepts for services or concepts for the distribution of products. The result must be significant in regard to productivity, improvement in the quality of a product or service, or savings on production and distribution costs.

Note: Companies in the innovation studies have at least 10 employees.

Source: CIS3.

Don’t forget small and medium-sized enterprises in the knowledge strategy

Name: Anker Lund Vinding
Position: Research assistant, Department of Business Studies, Aalborg University

Innovation creates growth

Product innovations contribute considerably to growth in companies and in the economy as a whole. A study of approximately 2,000 Danish companies shows that in companies which have introduced a product innovation between 1993 and 1995, employment increased by 6 per cent between 1993-1997. In contrast, employment in companies which did not introduce product innovations declined by approximately 3 per cent in the same period.

An average of all the companies included in the study shows a clear connection between the knowledge base and innovation activity of companies.

Companies which have academic workers and which form close contacts with knowledge institutions between 1993 and 1995 are much more likely to develop and market new products.

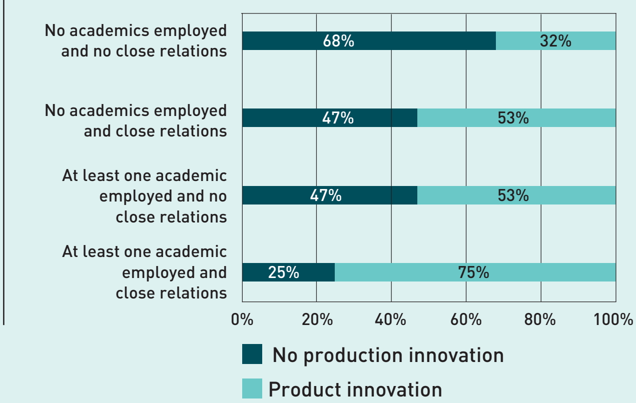
Strategy should embrace broadly

There is a distinct tendency for companies in knowledge-based and high-technology sectors, such as the pharmaceutical industry, the electronics industry and knowledge-intensive services, to use academic workers and to develop closer relationships with knowledge institutions. Therefore, it might be tempting to develop a national knowledge strategy focusing particularly on the needs of these companies and on their interaction with knowledge institutions.

However, several studies suggest that utilising academic workers and developing closer relationships with knowledge institutions do not explain very much about the differences in innovation activity within the knowledge-intensive industries and large companies. These two factors do, however, explain a great deal about the degree of innovation in small and medium-sized enterprises and in companies which operate outside the high-technology industry.

The results, therefore, suggest that small and medium-sized enterprises - particularly those operating outside the high-technology industry - need only a small grant to achieve considerable results. It requires a Danish knowledge and innovation policy with a wide embrace which does not focus solely on the interaction between high-technology companies and knowledge institutions.

Academics employed and trend in close relations with knowledge institutions and product innovation



Source: DISKO - spørgeskemaundersøgelse om organisation og innovation (questionnaire on organisation and innovation), 1996.

You can read more here:

www.business.auc.dk/~alv

Vinding A.L. (forthcoming) “Firms and Knowledge Institutions - Innovation Potential in Small Firms and Low-Tech Sectors,” in *Knowledge Creation and the Learning Economy*, Lundvall, B. A. and Keith Smith (Eds.).

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Collaboration on innovation and innovation networks

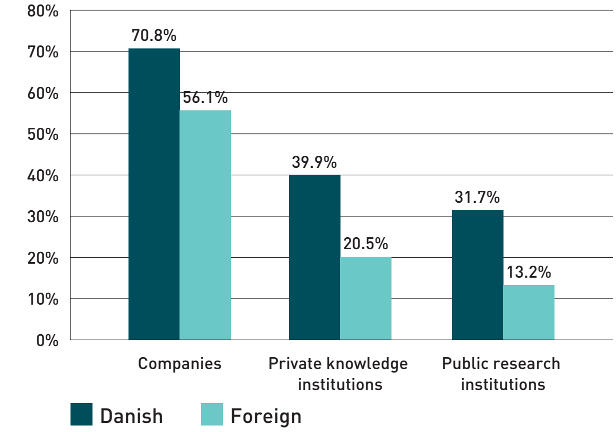
Commercial relations with customers, orderers and, to a lesser extent, competitors - make up a large portion of the companies' interaction and also play a large role in companies' innovations. Such interaction involves both formal and informal relations. These relations between companies can take the form of horizontal or vertical networks. That is, companies that operate in the same industry or companies that operate as subcontractors and customers in a value chain.

About 40 per cent of Danish companies that were innovative also collaborated with others on innovation in the period 1998-2000. When companies collaborate, they do so mostly with other companies, for example customers or suppliers. As figure 3 shows, of the companies that collaborated, 71 per cent did so with other Danish companies. 40 per cent of the companies have collaborated with private Danish knowledge institutions, that is, consultancies, private R&D institutes or technology service institutions. Companies, to a lesser extent, collaborate with public research institutions. 32 per cent of innovative companies did so.

In many cases, Danish companies also collaborate with foreign partners. At 56 per cent, foreign companies are the most commonly used collaborative partner for Danish companies that collaborated on innovation. Only 21 per cent of Danish companies that collaborated did so with private research institutes, and only 13 per cent did so with public research institutions.

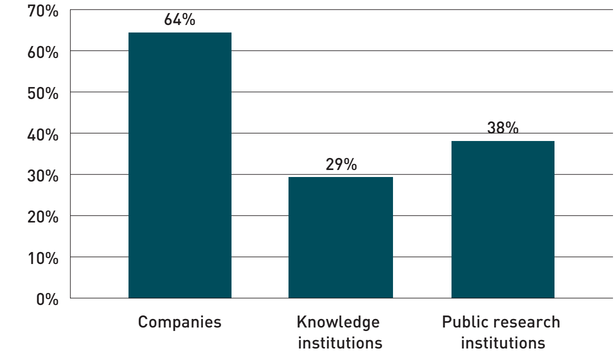
Danish companies vary greatly in the significance they generally attach to their collaborative partners in the innovation process. It is evident from figure 4 that companies attribute the greatest significance to collaboration on innovations with other companies. In this respect, 64 per cent of companies consider collaboration with other companies to be very important. Regarding collaboration with public research institutions, the figure is 38 per cent.

Figure 3: Innovative companies' collaborative partners, 1998-2000



Source: The Danish Institute for Studies in Research and Research Policy, Innovation study.

Figure 4: Percentage of collaborating companies that consider collaboration very important



Source: The Danish Institute for Studies in Research and Research Policy , Innovation study.

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Regarding collaboration with knowledge institutions, for example in the technological service field, 29 per cent of companies consider this very important.

Collaboration on research

For many companies, collaborating on R&D is a crucial element in their innovation process. In 1999, slightly more than half (54 per cent) of Danish companies that conduct R&D collaborated with others (see table 1). Nearly all of these (50 per cent of companies that conduct R&D) collaborated with other companies, while 25 per cent collaborated with public research institutions. That is, of these companies, twice as many as those that collaborated with public research institutions collaborated with private companies.

Table 2 shows that the large majority (87 per cent) of total private sector R&D is carried out in companies that have collaborated on R&D. These companies also account for about eight of every 10 R&D man-years (82 per cent). The average total R&D investment of companies that collaborated on R&D is five times as large as at companies that do not collaborate. There was also a distinctly higher researcher intensity of these companies (indicator of R&D man-years per R&D employee) than at companies that do not collaborate.

Table 1: Collaborative partners of companies that conduct R&D, 1999

Collaborative partner	Collaborates on R&D	
	No.	% of all companies that conduct R&D
Total private sector companies	955	50
Total public institutions	482	25
Total collaboration, all types and countries	1,044	54

Source: The Danish Institute for Studies in Research and Research Policy: Danske virksomheders forskningssamarbejde (Danish companies' collaborative research), 2002

Table 2: Characteristics of companies that conduct R&D, 1999

	Companies	Total R&D exp.	R&D man-years
Collaborates on R&D	54	87	82
Does not collaborate on R&D	46	13	18
Total (%)	100	100	100
No. and Total (DKK million)	1,925	18,670	21,022

Source: The Danish Institute for Studies in Research and Research Policy: Danske virksomheders forskningssamarbejde (Danish companies' collaborative research), 2002.

Entrepreneurs

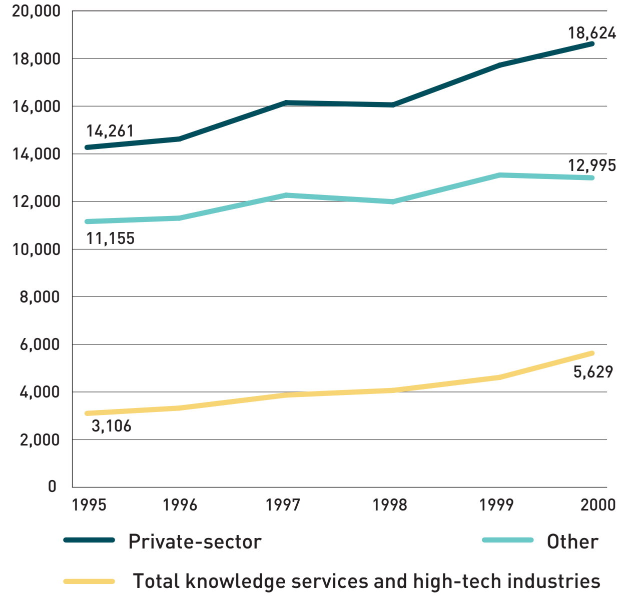
New companies and entrepreneurs can help to create dynamic developments in business and industry and economic growth through the creation of new jobs and innovation in the form of a renewal of production processes, services and products.

As figure 5 shows, in the period from 1995 to 2000, the Danish private sector saw the establishment of approximately 97,000 new companies. There was a steady rise in the number of new companies in the individual years during this period. The growth was lowest in 1995, when just over 14,000 were founded, and highest in 2000, when 18,624 were founded.

The trend varied from industry to industry. New companies in knowledge services and high technology industries have accounted for a growing share of all new companies in the period since 1995. In 1995, about 22 per cent of new companies were established in knowledge services and high technology industries, and in 2000, the corresponding figure was 30 per cent. This is representative of the general structure of business and industry, in which there has been a gradual shift towards knowledge-intensive production (for the definition of knowledge services and high technology companies, see chapter 5).

In order to evaluate the contribution of the new companies and their significance for economic growth in society, it is necessary to follow the companies over a longer period. Not all forms of renewal are capable of survival, and a portion of the new companies close.

Figure 5: Number of newly established companies, 1995-2000



Source: Statistics Denmark.

Figures 6 and 7 show the survival rate and growth of new companies in the shorter term, for the period 1994-98. Figure 6 shows that in 1994 nearly 15,500 new companies were established. Of this group, approximately 6,800 remained active in 1998. This yields a survival rate of 44 per cent for the period. Many companies close during the first two years after their founding, from this point on they become more capable of survival.

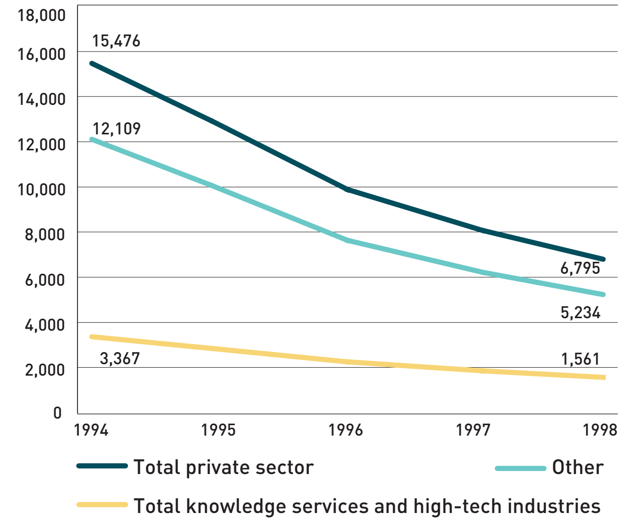
The survival rates of companies vary according to their industry. Companies in high technology and knowledge services industries have a higher survival rate than companies in other areas of business and industry. Among companies in high technology and knowledge services, almost 46 per cent remain active after four years, while the other companies have a survival rate of 43 per cent.

From an economic perspective, the number of new companies that survive is not the only important factor; it is also important how the surviving companies develop financially.

The average turnover at new companies established in the private sector in 1994 was just over DKK 500,000. In 1998, the average turnover rose to just over DKK 3 million, a growth of 151 per cent. Thus, there was steady growth throughout the period for new companies in the private sector as a whole.

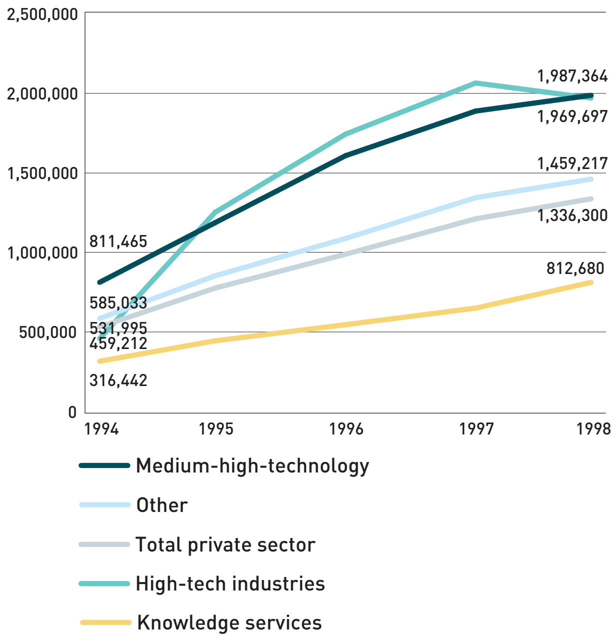
Figure 7 shows that there are large differences in turnover growth across business and industry segments. Companies in the high technology industry had the highest average turnover growth among companies established in 1994 that were still active in 1998 - DKK 1.5 million - or an increase of 329 per cent. However, turnover growth for new companies in knowledge services was limited. Their turnover growth was approximately DKK 800,000, equal to a rise of 157 per cent, during the period 1995-98. The average turnover level of these companies was also the lowest. Average turnover growth in the "other" segment of business and industry was the lowest of all categories, with growth of nearly DKK 875,000, or 149 per cent, during the period.

Figure 6: Number of companies started in 1994 that were still in existence in 1998



Source: Statistics Denmark.

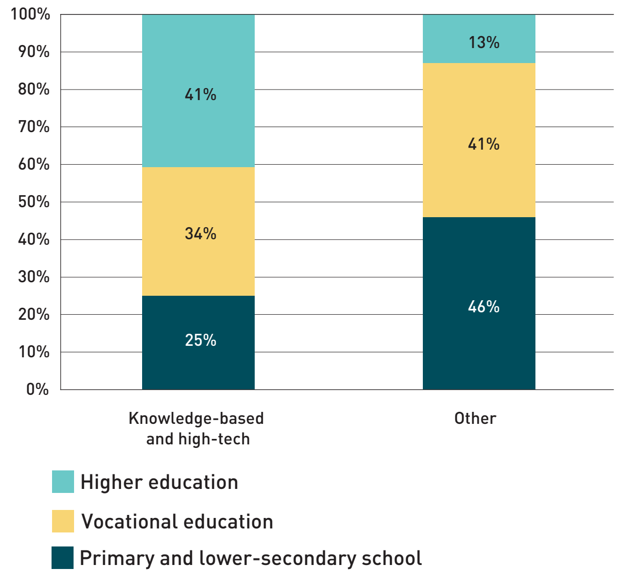
Figure 7: Average turnover of companies started in 1994 that were still in existence in 1998



Source: Statistics Denmark.

Education is a crucial factor in development of a business concept. But the educational level of entrepreneurs varies across industries. As shown in figure 8, the educational level for high technology and knowledge-based entrepreneurs is higher than that of other entrepreneurs. In 1999, more than 40 per cent of high technology and knowledge-based entrepreneurs had completed a higher educational programme, whereas only slightly over 10 per cent of the others had. For all entrepreneurs, however, between 31 per cent and 41 per cent had a commercial or vocational education. Among high technology and knowledge-based entrepreneurs, only 25 per cent did not have a business, vocational or higher education. In other categories, the corresponding figure is 46 per cent.

Figure 8: Educational level of entrepreneurs, 1999



Source: Statistics Denmark.

The high-technology entrepreneur is hard to put a label on >

Name: John P. Ulhøi
Position: Professor and head of research, PhD, Department of Organisation and Management, Aarhus Business School, the Social Networks and Entrepreneurs (SNE)Project

The results of a four-year study of high-technology entrepreneurs in Denmark show that it is very difficult to put a label on them. The empirical part of the research partly comprises data collected from a representative segment of all high-technology companies established in Denmark since 1996, and partly comprises personal interviews with 58 high-technology entrepreneurs. High-technology in this context is defined as information, communication, telecommunications, bio-tech and medico technology and life sciences.

The preliminary results put an end to previous theories on several points. Two examples of interesting results will be emphasised here.

Firstly, high-technology entrepreneurs increasingly establish their new companies in conjunction with "co-entrepreneurs" in so-called "entrepreneurial teams" which usually arise out of the entrepreneurs' social networks. In addition, we have been able to document that social networks are of vital importance to entrepreneurs. To this must be added that network relationships of various kinds meet a wide, but complementary, variety of purposes with regard to the continued development of new high-technology companies.

Secondly, the high-technology entrepreneur is not a uniform entity. There appear almost to be more differences than similarities, for example, when comparing entrepreneurs within the information, communication and technology sectors with entrepreneurs within the bio-tech sector.

As a result, considerable differences may generally be expected with regard to the entrepreneurial companies' industrial affiliation, entrepreneurs' motives, formal educational background, age, growth, exit strategy, degree of internationalisation and not least capital needs - including how easy or difficult it is for the entrepreneur to attract the necessary capital.

Initiatives aimed at furthering the terms of existence for high-technology entrepreneurs should, therefore, take into careful consideration these characteristics and differences which challenge the common perception of the entrepreneur as the "omnipotent" personality with "special characteristics" and which put an end to the idea that high-technology entrepreneurs should be viewed as a uniform entity.

You can read more here:

www.asb.dk/eok/org/staff/jpu_form.
htm http://www.org.hha.dk/org/mic/
http://www.org.hha.dk/org/lok/

Gattiker, U.E. and Ulhøi, J.P. (2000). "Entrepreneurial Phenomena in a cross-national context". In: R. T. Golembiewski, Ed. (2 nd Edition), *Handbook of organizational behaviour*. N.Y.: Marcel Dekker, Inc., pp. 389-441.

Christensen, Patrizia V.; Neergaard, Helle; Bøllingtoft, Anne; Fisker, Sannie; Ulhøi, John P.; and Madsen, Henning (2001). "Etablering og udvikling af nye innovative virksomheder - erfaringer og udfordringer" (The establishment and development of new innovative companies – experiences and challenges). Copenhagen: Nyt fra Samfundsvidenskaberne, p. 173.

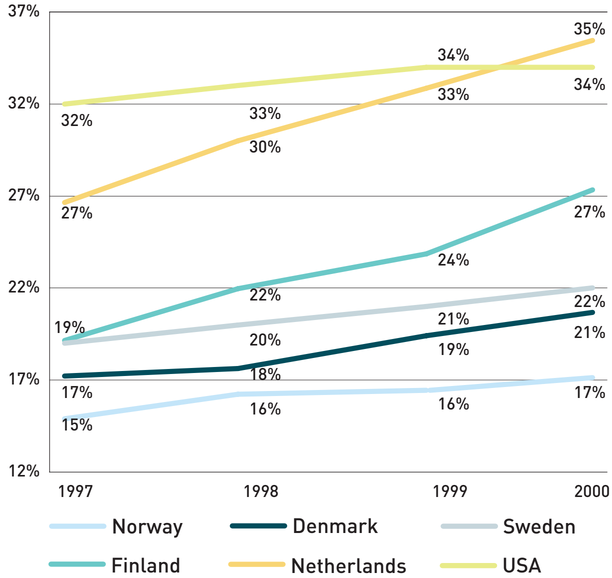
The results of innovation

The export of high technology products gives an indication of a country's innovation efforts and ability to convert knowledge from R&D and other areas into knowledge-intensive products. Figure 9 shows that in the period 1997-2000 there was a rise in the volume of high technology products as a percentage of exports in the manufacturing sector in a number of countries. This shows that knowledge-intensive production plays an increasingly large role in international trade.

Countries such as the Netherlands and the USA distinguish themselves from the other countries with high technology export shares of 30-45 per cent. Denmark has a high technology export share of approximately 20 on average for the period compared with the countries selected.

In a number of technology areas, for example engineering and biotechnology, it is essential for companies to protect their knowledge. This is often necessary in order to have the opportunity to exploit the commercial value that the knowledge is thought to contain. A common way of protecting such knowledge is patents. Patents are thus an important indicator of the results of innovation activity. They cannot be considered a comprehensive measure of R&D and innovation activity, however. For example, much new knowledge and many inventions are not patented or are not suitable for patenting.

Figure 9: High-technology products as a percentage of exports, 1997-2000



Source: World Development Indicators database.

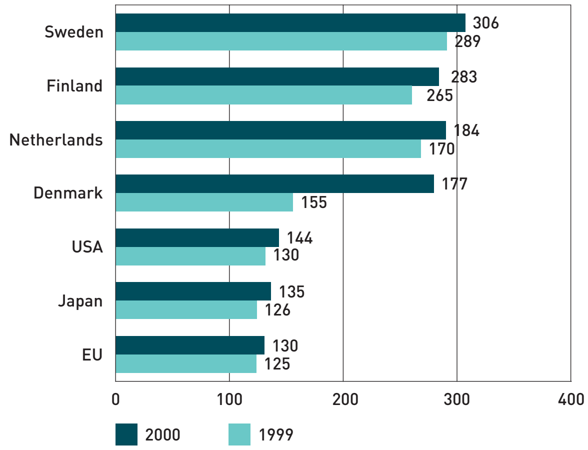
Patents

EPO patents:	The patent statistics for European patents include all applications for patents at the European Patent Office (EPO), including European PCT applications.
US patents:	The patent statistics for US patents include all patents approved by the US Patent and Trademark Office (USPTO).

Denmark lags comparable countries somewhat in the number of European patent applications. Sweden has 86 per cent more and Finland has 71 per cent more European patent applications per million inhabitants, than Denmark (see figure 10).

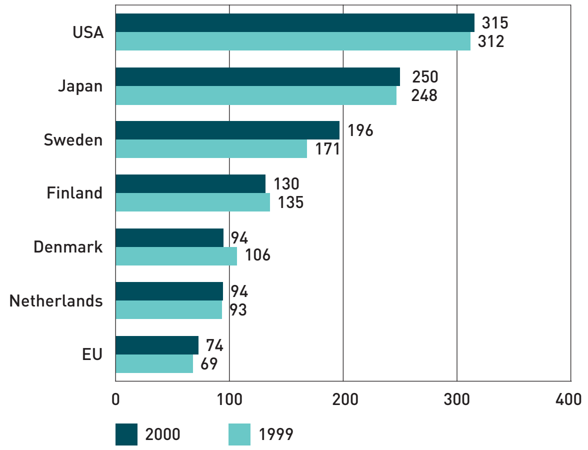
Figure 11 shows that Sweden also had 61 per cent more US patents approved per million inhabitants than Denmark did, while Finland had 27 per cent more approved. Overall, Denmark stands above the EU average.

Figure 10: European patents (EPO patent applications) per million inhabitants, 1999/2000



Source: European Commission: Key Figures 2001, 2002.

Figure 11: US patents (USPTO approvals) per million inhabitants, 1999/2000



Source: European Commission: Key Figures 2001, 2002.

The digital revolution

Name: Knud Erik Skouby
Position: Professor of Telecommunications Networks Economy and Regulation, Director of the Center for Tele-Information (CTI), Technical University of Denmark

Developments in information technology and telecommunications (IT/COM) have formed the foundation for a broader socio-economic development in which service functions and network relationships are becoming increasingly more important, and in which considerable changes in the structure of the business and industry community are taking place.

From monopoly to market

IT/COM has undergone fundamental changes in the last 10 to 15 years, both in Denmark and internationally. Central players have moved from having monopoly status to having to work according to regular market conditions and during that period the industry has moved towards greater internationalisation, especially on the shoulders of new players. This development has contributed to greater organisational challenges on the market, including the specific regulation of the telecommunications industry in particular.

The development is reflected in a very strong growth in turnover per full-time employee relative to other economic sectors which, again, reflects strong growth in the use of the sector's services. Today, the global IT/COM market accounts for more than USD 2,000 billion after an annual growth of more than seven per cent over the last decade.

Thus, the IT/COM industry's importance by far exceeds the obvious increase in the use of the industry's own products and services such as mobile phones and Internet connections - even though both have moved from practically nil to universal usage both privately and commercially.

A revolution for services
A considerable number of services of a data information or knowledge nature can be stored using electronic media and transmitted via electronic networks because the traditional telecommunications network is combined with and supplemented by other digital networks such as TV networks. This development increasingly involves the possibility of producing, distributing and consuming such services in new ways. In this way, the production of service functions can by partitioned, transported and made the object of division of labour - characteristics formerly reserved for material production.

The economic and social consequences of this development will be just as extensive as the mechanisation of manufacturing functions which constituted the "industrial revolution" of material production.

The interaction between technical and economic/ organisational and political/regulatory trends creates processes of change. These processes of change represent great problems, but also involve great opportunities for national economies as well as for the global economic system.

You can read more here:

www.cti.dtu.dk

Henten, A. and Skouby, K.E. (1997). "Implications of Information and Communication Technologies for the Internationalisation of Services," CTU Working Paper No. 32.

Henten, A., Skouby, K.E. and Øst, A. (1997). "Internet Economics," CTU Working Paper No. 33.

3.4 IT and telecommunications

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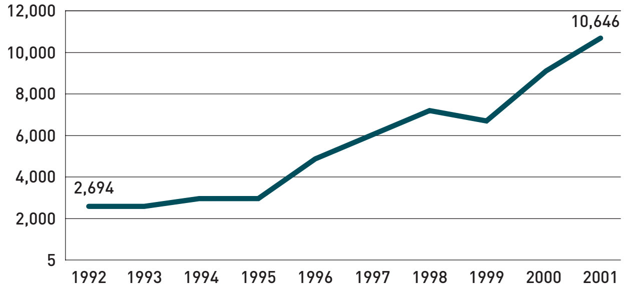
- In OECD comparisons of telecommunications prices, Denmark is generally placed in the top half of the rankings.
- The prices of fixed-line telephony have fallen by approximately 20 per cent since 1998. The prices of mobile telephony have fallen by 28 per cent, and those for traditional (dial-up) Internet access have fallen by more than 50 per cent.
- There are currently nearly 2.3 million Internet subscriptions in Denmark (private and business). An increasing number of subscriptions involve high-speed Internet access such as ISDN, ADSL and cable modem.
- In a European context, Denmark is one of the leading countries in the penetration and accessibility of ADSL. The prices of ADSL services in Denmark are among the lowest in Europe.
- 84 per cent of Danish households have a mobile phone.
- 65 per cent of households, have Internet access, giving Denmark a second-place ranking internationally.
- Most Internet users visit websites related to holidays and leisure, followed by sites about business and industry, then IT and technology.
- Denmark ranks as one of the world's leading countries in terms of the number of companies receiving orders via the Internet.
- Many industries outside the IT industry employ people with an IT education.

The telecommunications market

Since the liberalisation of the Danish telecommunications sector in 1995, investment in the sector has grown sharply. In 2001, total investments were more than three times higher than in the years before the liberalisation. In 2001, investments totalled DKK 10.8 billion (see figure 1).

Total turnover in the telecom sector has also risen since the liberalisation. From 1995 to 2001, total turnover nearly doubled, from DKK 19 billion to DKK 35 billion. The largest growth in the market took place in the areas of data communications, the Internet and mobile telephony.

Figure 1: Investment in the telecommunications sector, 1992-2001 (DKK million)



Source: Danish National IT and Telecom Agency.

Table 1: Annual turnover in the Danish telecom sector, 1992-2001

	1992	1993	1994	1995	1996
DKK million	15,807	16,449	17,803	18,880	21,116

	1997	1998	1999	2000	2001
DKK million	23,003	25,193	30,920	33,750	35,324

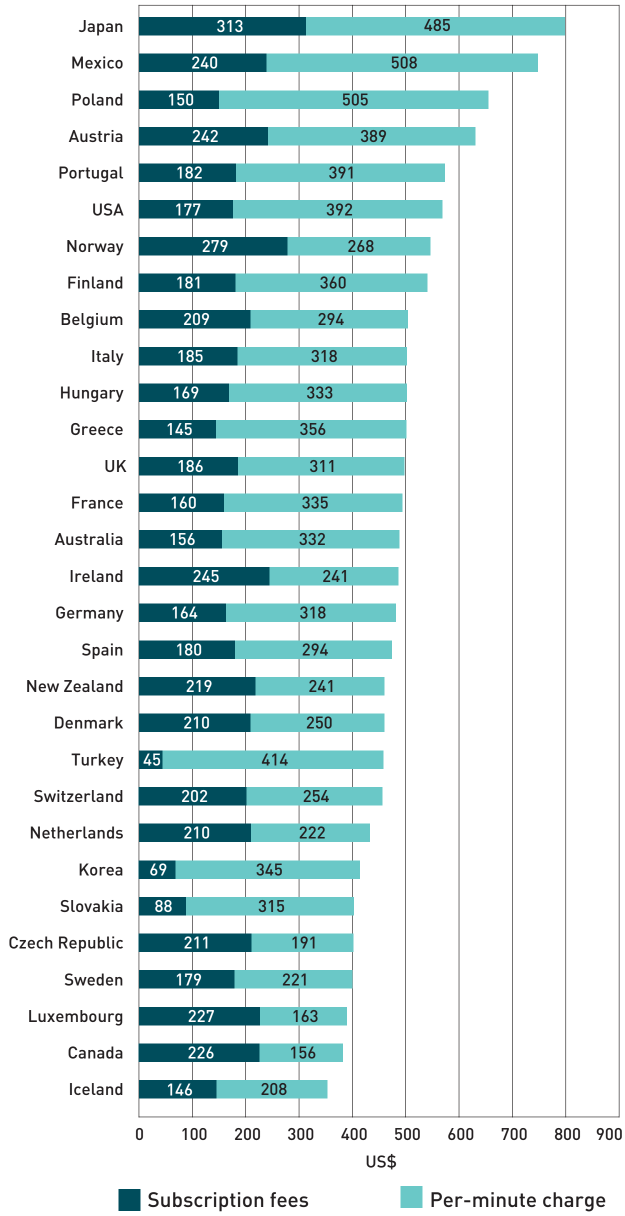
Source: Danish National IT and Telecom Agency

Fixed-line telephony

The number of fixed-line subscriptions is slowly increasing and by the end of the first half of 2002 numbered more than 3.9 million.

The price for 900 minutes of fixed-line telephony fell by 12 per cent over the period from August 1998 to August 2002, when calculated in current prices. If inflation is taken into account, this represents a drop in price of 20 per cent. Figure 2 shows that Denmark ranks 11th of the OECD countries compared. Adjusted for differences in VAT and purchasing power, Denmark ranks third.

Figure 2: Private consumers' annual expenses for fixed-line telephony (USD, incl. VAT)



Source: OECD Composite Residential Basket, Teligen/OECD, T-basket, August 2002.

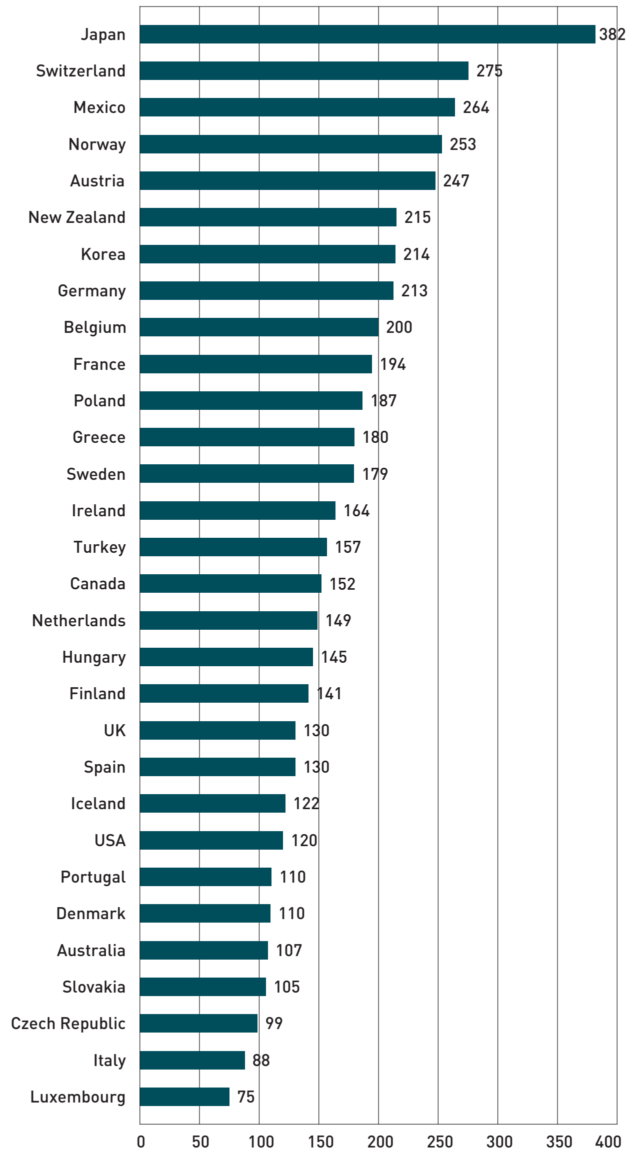
In mobile telephony prices, Denmark ranks sixth among OECD countries. Adjusted for differences in VAT and purchasing power, Denmark ranks second (see figure 3).

Internet

There are nearly 2.3 million Internet subscriptions in Denmark. This includes both private and business subscriptions.

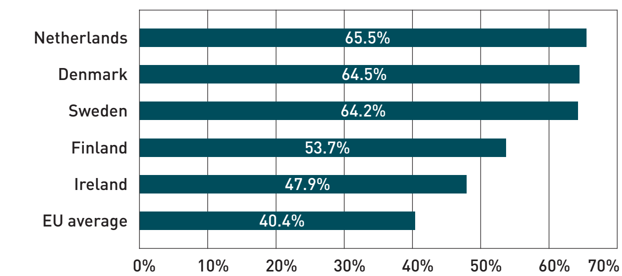
Compared with other European countries, Internet access is very widespread among Danish households (see figure 4). In June 2002, 65 per cent of Danish households had Internet access. This is much higher than the EU average and at about the same level as in Sweden and the Netherlands. The lowest-priced offer for 600 minutes of dial-up Internet usage per quarter fell by 51 per cent in the period from August 1998 to August 2002. This corresponds to a decline of 56 per cent, when adjusting for inflation.

Figure 3: Private consumers' annual expenses for mobile telephony (USD, incl. VAT)



Source: OECD Mobile Residential Basket, Teligen/OECD, T-basket, August 2002.

Figure 4: Spread of the Internet in the EU (households), 2002



Source: EU Commission, Eurobarometer, 2002.

High-speed Internet access

Denmark ranks near the top internationally in terms of access to and use of high-speed Internet connections. This trend primarily has accelerated in the past 12 months.

Danish consumers today have good opportunities to establish a high-speed connection to the Internet by means of several technologies – mainly ISDN, ADSL, cable modem and, to a lesser extent, FWA (fixed wireless access), which are the most common technologies. In addition, an increase in the number of LANs (local area networks) in housing associations, dormitories and the like is also expected.

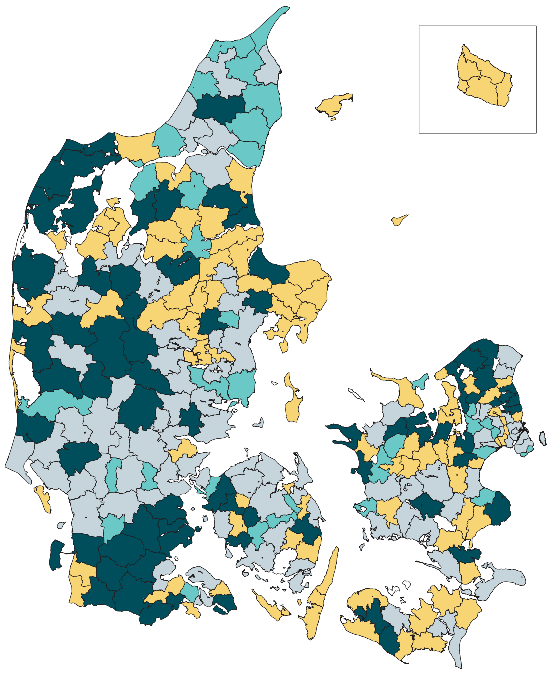
High-speed access is defined here as access which allows transmission speeds that are higher than those of ordinary dial-up modem connections.

The present accessibility of ADSL, cable modem and FWA in figure 5 is charted in a map of Denmark showing the number of access methods in each local authority. The map is based on information from the various telecom operators.

The map shows that in large regions of the country there are multiple alternative access methods such as ADSL, cable modem and FWA. In 80 local authorities (29 per cent), all three connection types are available; in 105 local authorities (38 per cent) two types are available; and in the remaining 90 local authorities (33 per cent), one type is available - ADSL. In addition, the competition among various ADSL service providers has grown sharply in the last year. All local authorities have at least two competing providers. In the larger urban areas, there are three to five competing providers.

Figure 6 shows that, in more than half of the local authorities, the penetration rate of ADSL and cable modem is 8 per cent or more of households and small and medium-sized enterprises. In 43 local authorities - primarily urban local authorities - the total penetration of ADSL and cable modem ranges from 15 per cent to 30 per cent.

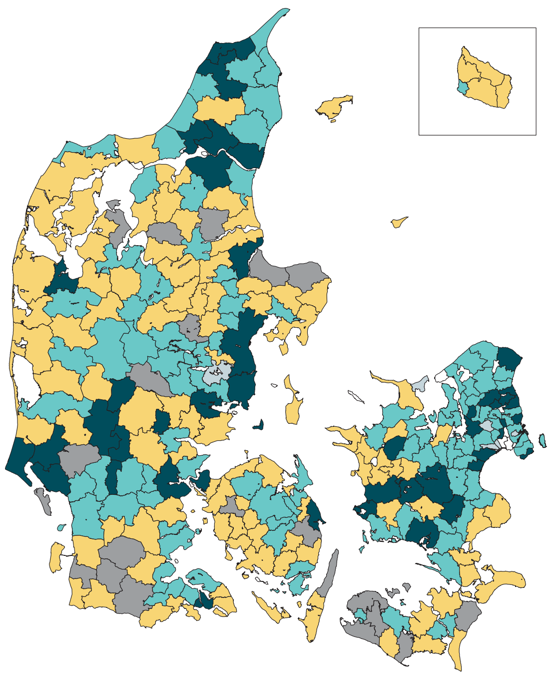
Figure 5: ADSL, cable modem and FWA (3.5 GHz), No. access types per local authority, mid-2002.



ADSL + cable modem + FWA (80)
ADSL + FWA (70)
ADSL + cable modem (35)
ADSL (90)

Source: Danish National IT and Telecom Agency.

Figure 6: Cable modem and ADSL - spread (% of households and small and medium-sized enterprises), mid-2002.



30 to 65 (6)
15 to 30 (43)
8 to 15 (97)
5 to 8 (108)
0 to 5 (21)

Source: Danish National IT and Telecom Agency.

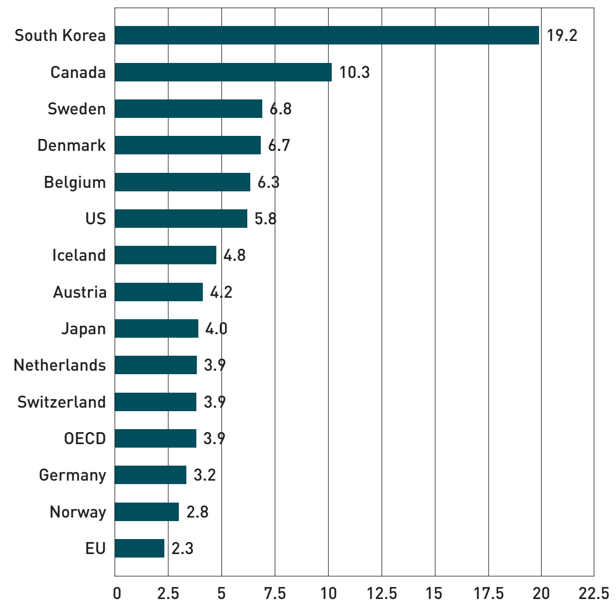
Denmark has one of the highest penetration rates for high-speed Internet access (ADSL, cable modem, FWA and LAN) in the world. In mid-2002, Denmark ranked fourth among OECD countries, with a penetration rate of nearly 7 high-speed connections per 100 inhabitants.

This corresponds to nearly 14 per cent of all households and SMEs. There has been a sharp increase since 2001, when the corresponding figure was nearly 5 per cent (Danish National IT and Telecom Agency).

Denmark's high ranking among European countries is owing largely to a sharp growth in ADSL subscriptions. The penetration of ADSL in Denmark is remarkably high by international standards. In September 2002, the research institute Point-Topic Ltd. (UK) published an overview of the penetration of ADSL in all the countries where the technology is available that compares the number of subscribers with the population figures. The study shows that in mid-2002 Denmark had the fourth-highest penetration rate in the world, exceeded only by South Korea, Taiwan and Hong Kong.

Denmark stands at the low end of the scale of ADSL prices in Europe. Figure 10 shows that only Belgium, Sweden and France had lower average ADSL prices than Denmark per 1 Mbit/s transmission capacity.

Figure 7: Spread of high-speed access to Internet* per 100 inhabitants, mid-2002



Source: OECD - December 2002.
*ADSL, cable modem, FWA and LAN.

Figure 8: ADSL prices in Europe - average price for 1 Mbit/s, ex. VAT, May 2002 (EUR).

Source: Teligen (UK) - May 2002. Prices in EUR, ex. VAT. Calculated average price of ADSL, 1 Mbit/s transmission speed, in the various European countries. ADSL services are not offered in Greece.

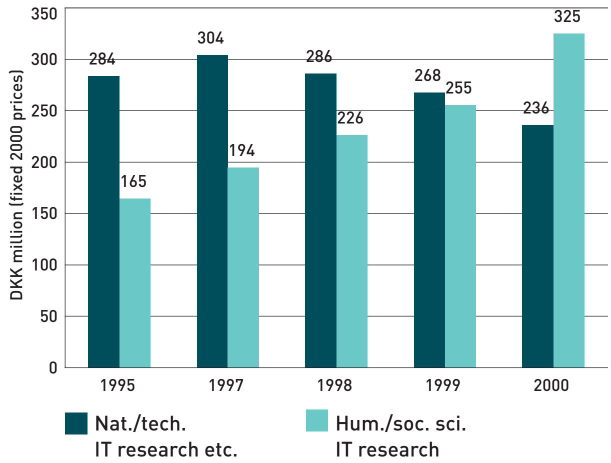
IT research

The breakdown in public investment in R&D has changed since 1997, with a shift away from IT research in the natural sciences and technical sciences and towards IT research in the humanities and social sciences. In 2000, DKK 236 million and DKK 325 million were invested in the two areas, respectively, in 2000 prices (see figure 9).

Danish business and industry invested approximately DKK 4 billion in R&D in the IT area in 1999, and approximately half was invested in software development, for example computer programs. Nearly one-quarter was used for programs integrated in other products, for example operating systems in robots and factory equipment, while DKK 700 million was invested in R&D in hardware. It should be noted, however, that a research project can include both hardware and software, so an investment may be counted twice in the study.

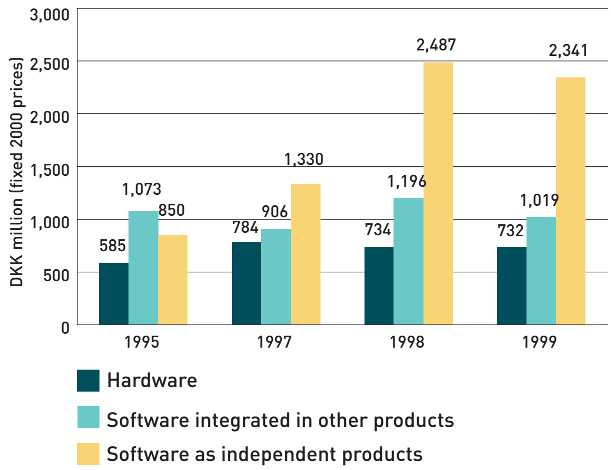
From 1995 to 1999, there was an overall increase in private sector investment in IT R&D of about DKK 1.8 billion. The largest increase occurred in the software area, where most of the development and adjustment of products takes place (see figure 10).

Figure 9: Public R&D in IT (operating expenses), 1995-2000



Source: Offentlig forskningsstatistik (Public sector research statistics) 1995-2000.

Figure 10: Private sector R&D in IT (operating expenses), 1995-1999



Source: Erhvervslivets forskningsstatistik (Private sector research statistics), 1995-1999.

Use of IT by the population

Figure 11 shows that 84 per cent of Danish households have at least one mobile phone. Of Danish households, 72 per cent have a PC, while 59 per cent have Internet access. Mobile phones are thus the durable consumer good that has seen the greatest increase.

More than half of the population that has completed a course of higher education uses the Internet daily (see figure 12).

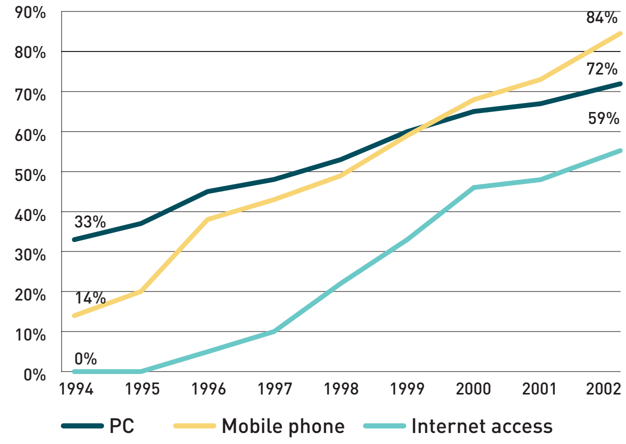
In comparison, only 21 per cent of the population with only a primary and lower-secondary education uses the Internet daily.

Figure 13 shows Internet use by Danes broken down by website topic. These figures are based on a direct recording of Internet users' habits during one week by means of a cookie installed on the users' PCs.

The art and culture category includes listings of events, music and film. The holiday and leisure category includes hobbies, personal websites and computer games. The people and health category includes exercise, personal contact and dating.

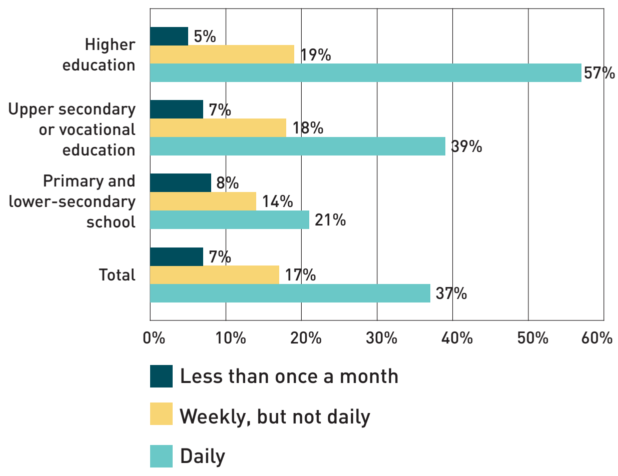
Figure 13 shows that six of 10 users visit websites about holidays and leisure. Only 8 per cent visited public websites in the observation period, while four of 10 visited IT and technology sites.

Figure 11: Households' possession of IT products, 1994-2002



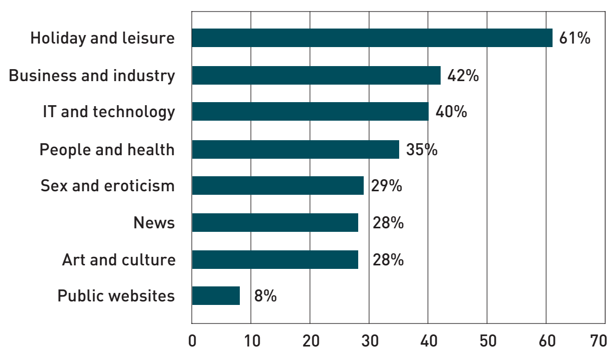
Source: Statistics Denmark.

Figure 12: Frequency of Internet use, by educational level, 3Q 2002



Source: Statistics Denmark.

Figure 13: Internet users' visits to websites, week 17, 2002



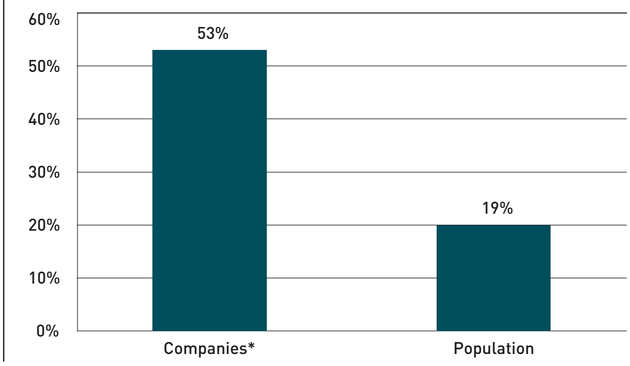
Source: Vilstrup Interactive.

Figure 14 shows that just over half of Danish companies with access to the Internet had contact with public authorities in 2001. For consumers, the corresponding figure was somewhat lower, at 19 per cent.

e-Commerce

In Denmark many more companies place orders over the Internet (47 per cent) than receive them (24 per cent). But in an international context, the percentage of Danish companies that receive orders via the Internet is rather large (see figure 15).

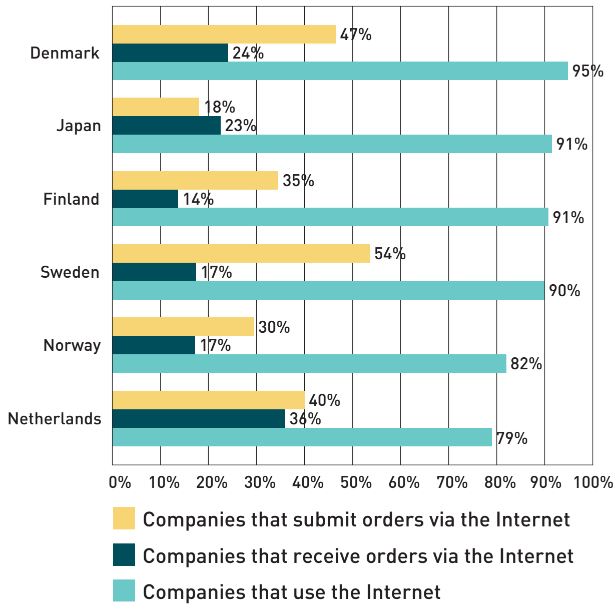
Figure: 14: Contact with public authorities, 2001



Source: Statistics Denmark.

* Companies with at least five employees with Internet access.

Figure 15: Internet commerce in companies (min. 10 employees), 2001



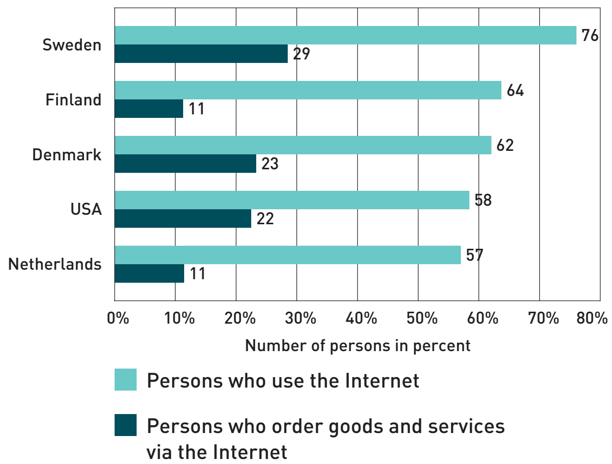
Source: OECD.

Figure 16 shows that a relatively large share of the Danish population (23 per cent) shop on the Internet; of the countries shown, only Sweden has a higher rate.

80 per cent of Internet sales go to other companies, and only 20 per cent go directly to consumers (see figure 17).

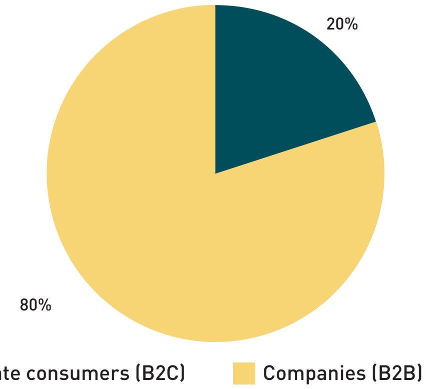
As shown in figure 18, one-third of all companies with Internet sales have integrated their sales with other IT systems. Most commonly this involved integration with order and invoice systems that make it possible to avoid transferring Internet sales data to traditional systems manually.

Figure 16: The population's e-commerce, 2001



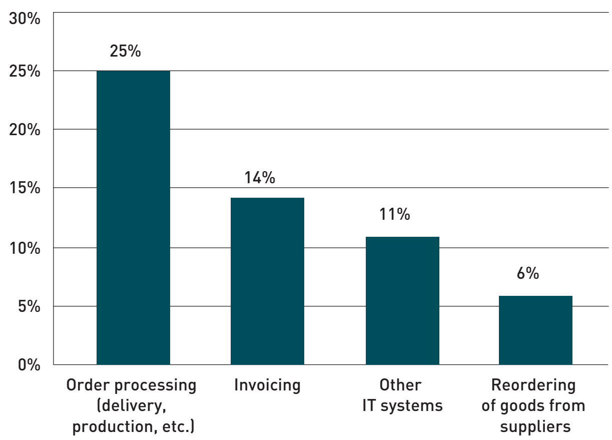
Source: OECD.

Figure 17: Companies' Internet sales broken down by customer group, 2001



Source: Statistics Denmark.

Figure 18: Integration of Internet sales with other systems, in companies with Internet sales, 2001



Source: Statistics Denmark.

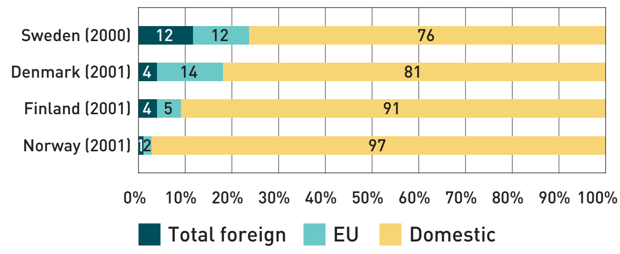
Denmark's Internet sales go primarily to the domestic market (81 per cent), while 14 per cent go to the EU and 4 per cent to the rest of the world. Thus, Denmark's Internet sales are more internationalised than Norway's and Finland's (see figure 19).

The IT labour market
Figure 20 shows the projections for the supply of graduates of IT educational programmes. In the period 1999-2010, the supply is expected to increase by nearly 30,000 people, so that in 2010 there are projected to be more than 80,000 trained IT professionals in Denmark. More than 10,000 of them will have a university degree (Master or PhD) in IT.

The growth is especially steep in short-cycle higher education (SHE), increasing the percentage of total IT trained professionals from 4 to 28 per cent. It should be noted, however, that data processing assistants fall under the vocational training (VE) segment, while data technicians are included in the short-cycle higher education segment. Since the training of data processing assistants was discontinued in favour of the training of data technicians, part of the high growth in short-cycle higher education enrolment can be ascribed to this shift from the vocational training segment.

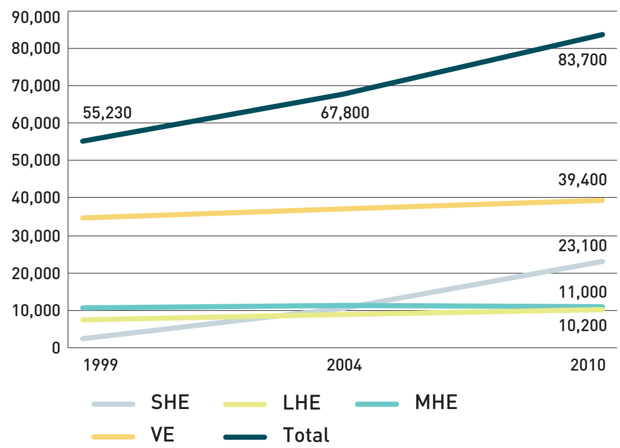
In 2001 and 2002, enrolment at the SHE level (data technicians and others) fell significantly.

Figure 19: Globalisation of Internet sales



Source: OECD.

Figure 20: Expected trend in offerings of IT educational programmes by educational level,* 1999-2010



Source: Danish Ministry of Education, Danish Ministry of Information Technology and Research, et al.: "IT-arbejdskraft og -uddannelser - udbud og efterspørgsel" (IT Personnel and Qualifications - Supply and Demand), 2001.

* Maintenance of 2000 intake, graduation percentage, etc.

As shown in table 2, many industries besides the IT industry employ people with IT training and/or people who fill IT positions. These include industries that produce machinery, electrical equipment and medical equipment as well as service companies such as financial institutions and insurance companies.

Central government IT investment

The Ministry of Finance calculated the total projected central government investment in IT in 2001 to be DKK 1.3 billion. Administrative systems are expected to constitute the largest individual item, accounting for 40 per cent of total investments (see figure 21). The Internet also represents one of the largest investments, since it is expected that 27 per cent will be reserved for this area.

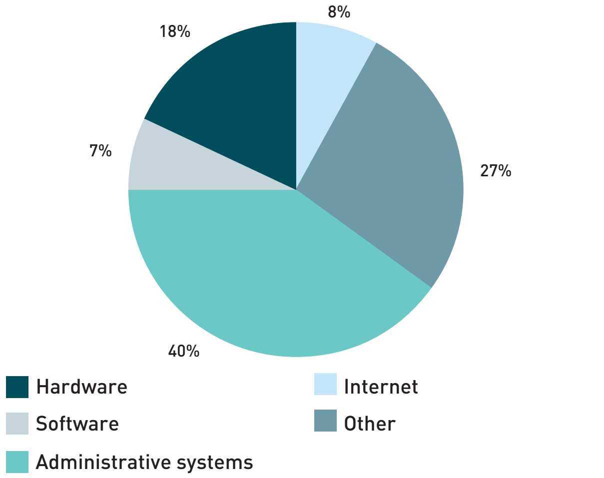
Table 2: Combination of IT positions and IT education, 2001

	With IT positions		Without IT positions		
	With IT educ.	Without IT educ.	With IT educ.	Without IT educ.	Total
Engineering industry	916	3,046	1,212	63,516	68,690
Manufacture of other electrical machinery and equipment	1,056	2,928	1,130	15,026	20,140
Manufacturing of medical equipment, instruments, clocks, etc.	1,218	2,408	912	11,660	16,198
Elec., gas and heat supply	285	1,276	336	10,714	12,611
Financial institutions and financing companies	1,066	2,637	408	51,481	55,592
Insurance companies	290	943	156	15,352	16,741
Research and development	269	594	339	10,098	11,300

Source: Statistics Denmark.

Note: Only industries outside the IT industries with the highest percentage of IT positions and IT-educated employees in the industries are shown.

Figure 21: Expected central government IT investments, 2001

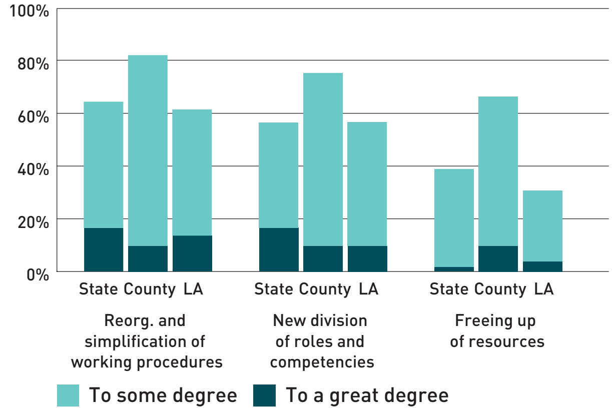


Source: Ministry of Finance, "IT, Internettet og den offentlige sektor IT" (The Internet and the public sector), June 2000.

Besides having a direct significance for citizens and companies through digital administration, the many investments also have significance for authorities' internal organisation. Most often, the projects lead to reorganisation and simplification of work routines. This takes place at 6 out of 10 authorities to some degree or to a great degree (see figure 22).

However, in the majority of cases, the projects do not free up resources at the central government or local authority levels. The reason might be that benefits of the projects regarding the use of resources have not yet been realised. But the figures also show another factor. The public authorities that have restructured their work procedures and the delegation of competencies in connection with digitalisation projects, free up a portion of their resources more often than those that have not.

Figure 22: Changes in tasks in response to digitalisation projects, 2002



Source: Statistics Denmark: Den offentlige sectors brug af IT (The public sector's use of IT), 2002.

>

> Value added at high technology companies in 2000 was just over 2 per cent of total production. This places Denmark slightly above the average for the EU, but lower than Sweden and Finland.

> The 50 companies with the highest R&D investment level in Denmark account for almost half of the investment in R&D by business and industry.

> In 2000, there were 1,819 knowledge-intensive companies in Denmark. This represents 3 per cent of all companies with five or more employees.

> The knowledge-intensive companies employ two-thirds (40,000) of all knowledge workers (60,000) at Danish companies with more than five employees. Knowledge workers are those with a university degree (Master or PhD) university degree (Master or PhD).

> The three focus areas - IT industry, media/communications and pharmaceuticals - together account for more than half of R&D in Danish business and industry, although the turnover in the areas represents only about 14 per cent of total turnover in business and industry.

> Of employees in the pharmaceuticals industry, 1.6 per cent hold a PhD, while the corresponding figure for Danish business and industry generally is 0.2.

> The profit level in the pharmaceuticals industry, at DKK 600,000 per full-time employee, is twice as high as profits in the rest of business and industry.

>

4.0 Introduction

This chapter describes how the various segments of Danish business and industry have integrated R&D, education, innovation and IT/telecommunications in their daily work.

First, the chapter outlines the composition of the segments of Danish business and industry that the OECD, according to the companies' R&D intensity, categorises as high technology companies, medium-high technology companies and knowledge services companies. This enables a determination of the economic significance of these company segments.

The OECD's method does not give a precise picture of the Danish companies that conduct R&D and of how they perform financially. The reason is that the OECD method includes a number of companies that do not conduct much research and development. This chapter therefore contains a new study that shows that very few companies carry out most of the R&D in Danish business and industry. It also becomes clear that these companies are found not only in the industries that the OECD characterises as high technology industries. Some medium-high technology companies also cultivate R&D intensively.

In connection with this report, we have created a data set in which the individual companies' R&D is linked to key figures on finances, employment etc. based on official registers. This makes a more precise study of the effect of R&D on the individual company's financial capacity possible.

The chapter also contains an analysis of the companies' ability to absorb new knowledge and use it in new products and processes. This is a new approach based on the relation between the employees' education and the companies' growth.

In order to make the results and conclusions more concrete, they will be related on an ongoing basis to the three focus areas: IT industry, media/communications and pharmaceuticals.

The analysis identifies knowledge-intensive companies, that is, companies that to a great degree aim to hire and retain knowledge workers, who have a university degree (Master or PhD). Highly educated employees are an important precondition for a company's ability to use new technologies and create new knowledge. Thus, these employees are also the foundation for value added by the companies.

Finally, we analyse the three focus areas in Danish business and industry. The distinctive aspect of these areas is that they have many knowledge-intensive companies that have made extensive use of R&D, highly educated labour, innovative abilities and IT.

Other focus areas might be just as relevant, but the areas selected have been brought forth as examples of industries in which companies make a great effort to use the four driving forces.

The studies are based on a combination of data collected from random samples and from official registers. The most recent register data are from 1999/2000, and the random sample data are from 1999 to 2001. Recent changes are therefore not included in the data. This applies, for example, to the recent downturn in certain segments of the IT industry, which it is not reflected in the figures.

Companies' investments in R&D result in productivity gains

>

Name: Valdemar Smith
Position: Associate Professor at the Department of Economics, Aarhus School of Business; Member of the Centre for Industrial Economics, Institute of Economics, University of Copenhagen

A number of studies of economic growth have in consensus shown that quite a substantial part of this growth must be explained by factors other than the development of efforts involving the usual production factors, i.e. human labour and capital. This acknowledgement is in full accordance with the endogenous growth theory in which knowledge of and thereby investment in R&D play a central role in the companies' productivity and consequently in their financial growth.

Taking the concept of production function (described in the chart below) as their point of departure, Smith, et al. (2002) use information on the annual R&D expenditure of 200 Danish companies since 1987 to analyse the productivity effects of R&D investments in Danish companies. For each company, an accumulated R&D capital is calculated for 1997. A distinction is made between the actual number of research personnel and the accumulated R&D capital, which the companies have built up since 1987, the latter assuming that the annual write-off of R&D is 20 per cent.

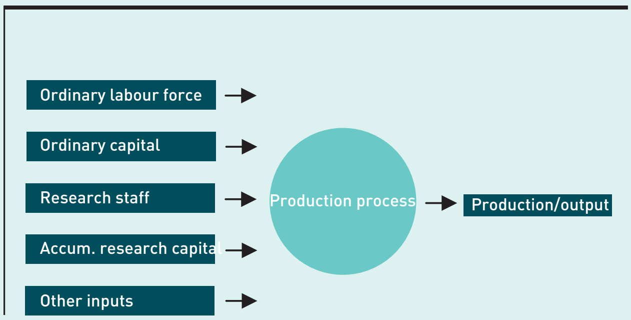
Among other things, the model predictions show that IF the accumulated R&D capital of private companies increases by 1 per cent through new R&D investments, productivity and consequently the size of production on average increase by approximately 0.08 - 0.12 per cent.

This result is in accordance with American studies. The magnitude of the R&D effect must be viewed in light of the fact that a concurrent increase of *all* input by one per cent according to the model predictions is expected to increase the size of production by one per cent. On the other hand, the quite short-term effect of increases in research personnel is more limited, which emphasises the fact that the R&D effort generally operates with several years' delay.

In a later study, Dilling-Hansen, et al. (2002) find that R&D-active companies are (technically) more efficient than companies with no R&D expenditure.

The study, which shows relatively significant results, is based on a single year's parallel processing of information from Danish R&D statistics with financial statements information for the individual companies. Thus, the study does not take into consideration the dynamic effects described above. On the other hand, the calculations are based on information from almost 2,400 companies.

The dynamic aspects of the effects of R&D are analysed more closely in Bentzen & Smith (2001). Based on aggregate data from 1978-1998, the study reveals that new R&D capital probably affects the productivity of companies with an average delay for the entire business and industry community of two years.



You can read more here:

www.asb.dk/eok/nat/staff/vs_form.htm

Bentzen, J. and V. Smith (2001): "The Short-Run Impact of Business Sector R&D Activities on Total Factor Productivity: Empirical Evidence from The Danish Economy". In: *Journal of Global Business*, Vol.12, no. 23, pp 5-14.

Dilling-Hansen, M., E.S. Madsen and V. Smith (2002): "Efficiency R&D and Ownership - some empirical Evidence" (Forthcoming). In: *International Journal of Production Economics*.

Smith, V., M. Dilling-Hansen, T.Eriksson, E.S.Madsen: "R&D and Productivity in Danish Firms: Some Empirical Evidence." WP2000/4, The Danish Institute for Studies in Research and Research Policy, Aarhus, 2000.

4.1 High technology, medium-high technology, and knowledge > services companies in Denmark

> The OECD classifies business and industry into a number of industries based on their R&D intensity. A comparison of Denmark with the other OECD countries on this basis shows that Danish business and industry performs as the average in terms of the high technology industries' shares of value added and employment.

> Value added at high technology companies in 2000 was just over 2 per cent of total production. This places Denmark slightly above the average for the EU, but lower than Sweden and Finland.

> Employment in knowledge services constituted 11 per cent of total employment in Danish business and industry in 2000. This is almost as high as the EU average, but lower than the levels in the USA and the Netherlands, at 15 and 18 per cent respectively.

> The businesses that conduct intensive R&D are placed in several different industries in Denmark, in both the industrial and knowledge services sectors.

> The 50 companies with the highest R&D investment level in Denmark account for almost half of investments in R&D by business and industry.

>

Introduction

There were a total of 236,000 companies in the private sector in Denmark in 1999. About 166,000 of them were service companies, and 27,000 were industrial companies. The rest is e.g. construction companies. Service companies are usually small. There were 407,000 full-time employees in the service sector and 554,000 in the industrial sector.

The OECD divides the industries in the service and industrial sectors according to R&D intensity. The classification has three categories that are relevant in this context: high technology industries, medium-high technology industries and companies that work in knowledge services.

High technology companies are usually large manufacturing companies, such as those in the pharmaceutical, IT and telecom industries. Medium-high technology companies fall into the chemicals, engineering and electronics industries and also include companies that manufacture various means of transport. Knowledge services companies are usually smaller companies that provide consulting, research and marketing. Further examples of the classification are shown in the section on method.

Box 1: The OECD's classifications

The OECD's statistics should make it possible to compare countries. It is therefore necessary to have broad industry definitions that can be harmonised.

This could apply, for example, to the manufacture of office machines, an industry in which the small Danish companies do not necessarily conduct research and development, whereas Xerox and Hewlett Packard conduct extensive R&D.

It is thus the broadest common denominators that have been used to classify industries.

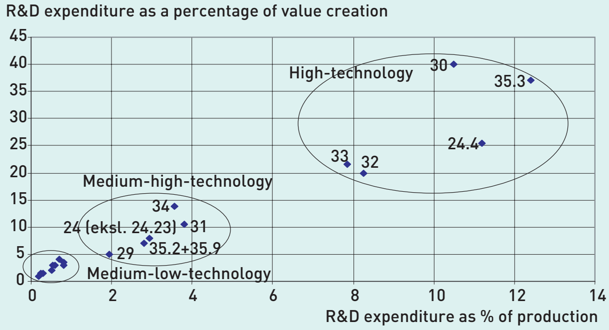
The OECD classifies technology-intensive industries on the basis of these principles regarding the intensity of their research and development:

1. R&D expenditure in relation to value added.
2. R&D expenditure in relation to production.

The OECD classifies industries in the following segments:

> High technology
> Medium-high technology
> Medium-low technology
> Low technology

Aggregate R&D intensity in OECD countries, 1977



Source: OECD, STI Scorecard 2001, p. 138.

Note: The figures in the chart are the industry codes that are used in statistical publications. See also the section on method.

Table 1: Size of knowledge industries in Denmark

	Full-time employees, 1999	Growth in full-time employees from 1995 to1999	Turnover in 2001 (DKK 1,000)	No. com-panies, 1999
High technology	42,917	7%	72,513	1,445
Medium-high technology	101,043	-2%	138,317	4,765
Knowledge services	93,397	28%	131,424	42,162
Other	873,568	8%	1,805,818	187,776
Total private sector	1,110,925	8%	2,148,072	236,148

Source: Statistics Denmark.

Note: The financial and insurance industries are not included in knowledge services as in the OECD's classification. Total private sector is private-sector urban industry.

The figure below shows the OECD classification. It shows that the high technology industries are the pharmaceuticals industry (Nace 24.4 and 33), parts of the IT industry (Nace 30), the telecom industry (Nace 32), and aircraft manufacturers (Nace 35.3). Further examples of the classification are shown in the section on method.

Knowledge-based service companies

The OECD has selected a number of service industries in which knowledge intensity is especially high. They include IT service companies, legal and engineering companies, and banking and financial companies. See the section on method for further descriptions.

Table 2: Employees in knowledge industries with university education, 2001

	Employees	Employees with university education*	University-educated
High technology	43,325	4,635	11%
Medium-high technology	113,247	4,511	4%
Knowledge services	164,610	39,205	24%
Other industries	1,442,932	49,285	3%
Total private sector	1,764,114	97,636	6%

Source: Statistics Denmark, uddannelsesstatistikken (education statistics).

Note: University-educated employees hold a bachelor degree, candidatus (master) or a PhD degree.

Table 1 shows the size of the various industries in Denmark. It shows that there are 1,445 high technology companies, 4,765 medium-high technology companies and 42,162 knowledge services companies. The knowledge services industry consists of many small companies with an average of fewer than three employees. The high technology companies have the highest number of employees on average, 30, followed by medium-high technology companies, which average 21 employees.

Table 2 shows that knowledge services and high technology companies have the highest percentage of employees with a university education.

Almost every fourth employee in knowledge services has a university education, while in high technology the figure is one in 10. Altogether, half of all university-educated employees work in knowledge services.

The high- and medium-high technology industries contribute five and six per cent of value added, respectively, in the Finnish economy. The corresponding contributions to the Danish economy are 2 and 4 per cent. Denmark's knowledge services account for 12 per cent of value added. This is the same level as in Sweden, higher than in Finland, but lower than the EU average.

In Denmark, 1.5 per cent of employed persons work in the high technology industry. That is almost as high as the average for the EU and the OECD, but lower than in the USA, Finland and Japan, where employment in the high technology industry is between 2 and 2.8 per cent.

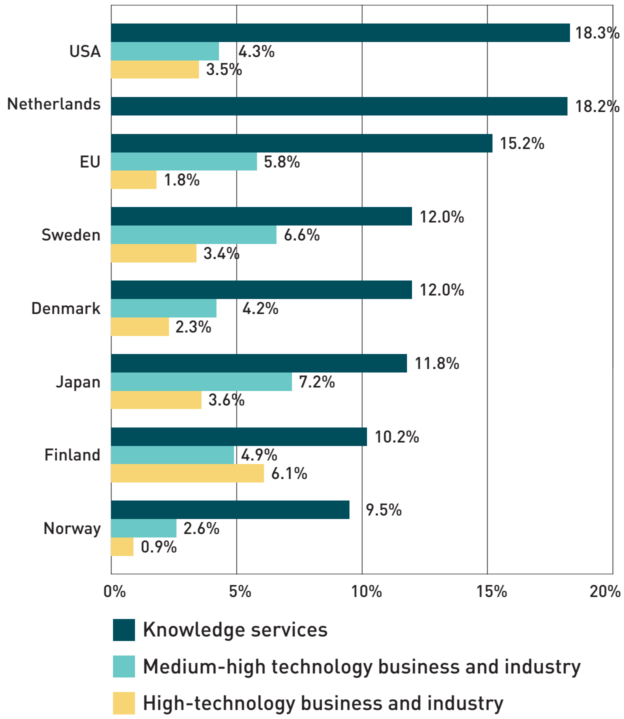
Danish employment in knowledge services is 11 per cent and thus higher than in Japan, Finland and Sweden. In the USA and the Netherlands respectively, 15 and 18 per cent work in knowledge services.

By Western European standards, Danish business and industry is thus not particularly technology- and knowledge-intensive, but perform rather average.

The OECD's method of calculating the number of high technology companies, may, however, result in a simplistic picture of Danish business and industry.

There are a total of 1,445 high technology companies in Denmark, according to the OECD's definition, which counts all companies in a given industry. That is, it also includes companies that do not have their own R&D activity. There is a relatively large number of these companies in Denmark because of the structure of the country's business and industry in which R&D is concentrated in a few companies. This situation distorts the result of the analysis.

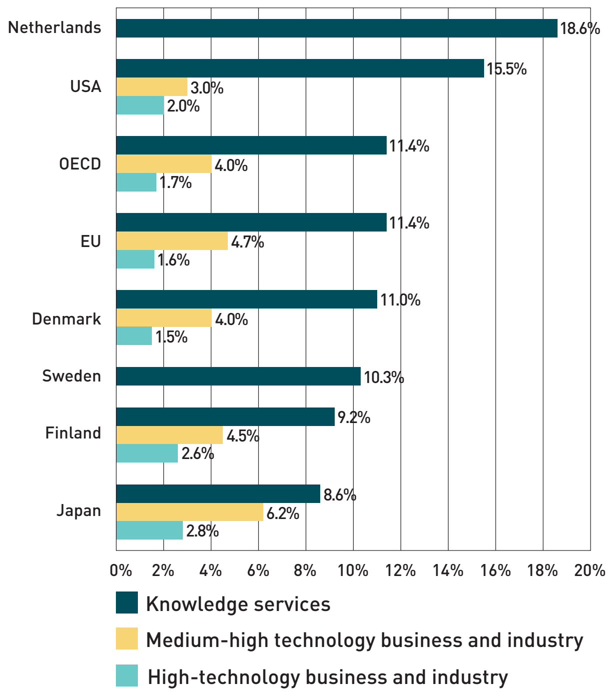
Figure 1: Value added as a percentage of total value added, most recent year*



Source: OECD Science, Technology and Industry Outlook, 2002.

* 1999 or 2000.

Figure 2: Employment as a percentage of total employment in the private sector, 2000*



Source: OECD Science, Technology and Industry Outlook, 2002.

* 1999 or 2000.

If one wishes to make an accurate analysis of the companies in Denmark that are very R&D-intensive, it is necessary to start with the individual company that has pronounced R&D activity.

A special study of the R&D-intensive companies in Denmark and a review of the largest R&D companies in the country can illuminate this issue. See boxes 2 and 3.

The most R&D-intensive companies in Denmark, measured by R&D in relation to turnover and gross profit, show that there are many different types of R&D-intensive company.

If the OECD's classification of the high technology industry is used, it turns out that one-third of R&D work in Denmark is conducted at R&D-intensive companies.

Box 2 shows that there are 247 R&D-intensive companies, and 23,935 persons are employed at these companies. This figure includes 83 industrial companies and 159 knowledge services companies. It should be noted, however, that this is a random sample. If the figures are aggregated and weighted, there are 413 R&D-intensive companies. The OECD classifies only industrial companies, and that is why the figures are not completely comparable.

Total investment in R&D by Danish business and industry in 1999 was DKK 16.1 billion. Almost half of this investment - 45.5 per cent - was made by the 50 companies that invest the most in R&D. Thus, R&D investment was very concentrated.

It should be noted that total investment in R&D in 1999 was revised in the research statistics for 2001.

Among the 50 companies most active in R&D are both industrial and service companies. There were 16 companies in the IT industries, 8 in pharmaceuticals and 26 in other industries. Pharmaceuticals and IT industries are two of the focus areas that are analysed in section 4.3.

The eight pharmaceutical companies accounted for the largest R&D investment, DKK 2.8 billion. This means that slightly under one-sixth of the total investment in R&D by Danish business and industry is concentrated in these eight companies. In comparison, the 16 IT companies in the top 50 had R&D investments of DKK 2.3 billion, or one-seventh of total R&D investment by business and industry.

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Box 2: R&D-intensive companies

The companies in Danish business and industry that invest intensively in R&D provide an indication of the structure of Danish business and industry. By making a classification of the high technology industries that assumes that companies must invest at least 16 per cent of their gross profit in R&D and also invest at least 6 per cent of their turnover in R&D, one can isolate the companies that make major efforts in R&D.

Such a classification also shows to what degree the OECD's industry classification captures the Danish R&D-intensive (high technology) companies.

The table below shows that there are 247 R&D-intensive companies and that only 54 of them belong in the industries that the OECD calls high technology and that 159 belong under knowledge services. The table also shows that the 247 R&D-intensive companies employ 23,935 full-time employees and that there is an average of 97 full-time employees at the companies.

The 247 R&D intensive companies invest approximately DKK 5 billion, or one-third of all R&D investment in Danish business and industry. In comparison, they employ only 2 per cent of the total labour force in business and industry. The gross profits of the R&D-intensive companies were almost DKK 19 billion.

R&D-intensive companies[1]

	No.	R&D investment (DKK million)	Turnover (DKK million)	Gross profit (DKK million)	Payroll etc. (DKK million)	Full-time employees	Avg. full-time employees
Chemicals (Nace 24)	9	968	5,211	4,175	1,372	3,544	394
Manufacture of other electrical machinery and equipment (Nace 31)	6	22	131	68	44	140	23
Manufacture of telecommunications equipment (Nace 32)	19	348	2,408	1,229	680	2,249	118
Manufacture of medical equipment, instruments, clocks, etc. (Nace 33)	27	678	4,653	2,870	1,466	4,400	163
Other industries	22	264	1,577	840	511	1,704	77
Total industry	83	2,280	13,979	9,183	4,073	12,037	145
OECD high technology total (Nace 24.4, 30, 32, 33, 35.3)	54	1,725	10,882	7,266	3,023	8,907	165
Data processing companies (Nace 72)	86	943	3,051	2,458	1,267	3,141	37
Research and development (Nace 73)	33	758	1,668	1,289	920	2,385	72
Other business services (Nace 74)	40	467	1,846	1,347	887	1,990	50
Total knowledge services	159	2,169	6,566	5,094	3,074	7,516	47
Other	5	847	10,193	4,276	2,276	4,382	876
Key figures	247	5,297	30,738	18,553	9,423	23,935	97

Source: Statistics Denmark: General company statistics and Danish Institute for Studies in Research and Research Policy.

The criteria are that the companies' R&D investment must be 16 per cent of gross profit and 6 per cent of turnover. The figures are based on random samples of research statistics and not aggregate analyses. If the figures are weighted, there are 413 R&D-intensive industrial and services companies - much lower than the 1,445 industrial companies that result from the OECD's categorisations.

In relation to the OECD's industry classification, this classification on the basis of R&D intensity gives a more precise picture of the structure of Danish business and industry, in which companies from many different industries are active in R&D. The OECD's classification of high technology industries includes only four of the eight categories since the OECD is concerned solely with industrial companies. In addition, the manufacture of other electrical machinery is not high technology work but medium-high technology work in the OECD's classification. Finally, 159 of the 247 companies are knowledge services companies, which are not included in the OECD's classification.

The 247 R&D-intensive companies are based on a random sample; if the figures are weighted, there are 413 R&D-intensive industrial and services companies – which is considerably less than the 1,445 industrial companies that result from the OECD's categorisation.

The 50 companies with the largest R&D investments have a total of 76,942 full-time employees. The IT companies in the top 50 have the largest share, with 26,612 full-time employees. Pharmaceutical companies have 11,484, which is less than half the number at IT companies.

The eight pharmaceutical companies in top 50 have the highest turnover, the highest gross profit and the highest IT investment per full-time employee. The turnover and gross profit per full-time employee are DKK 1.9 million and DKK 1.5 million respectively. In comparison, the IT industries have an average turnover of DKK 1.5 million per full-time employee and an average gross profit of DKK 1.1 million. The gross profit for the top 50 companies is much higher than in the rest of Danish business and industry.

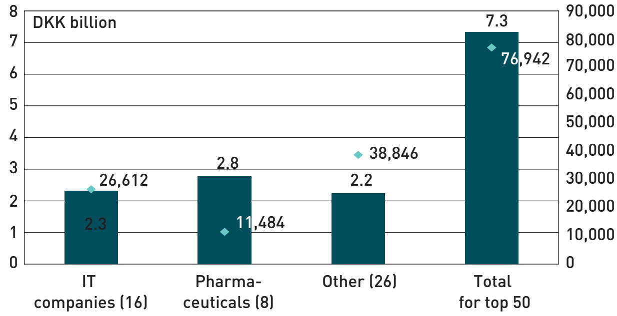
The pharmaceutical companies invest almost three times as much in R&D per full-time employee as the IT industries: DKK 242,000 versus 87,000.

The conclusion is that R&D in Denmark is concentrated in very few industries and relatively few companies.

It is therefore necessary to look at the individual companies to obtain a more precise picture of the significance of high technology (R&D-intensive) companies. This will be done by outlining the companies' R&D work and linking it to the financial data. Then it will be possible to see whether the R&D-intensive companies actually are financially stronger than other companies.

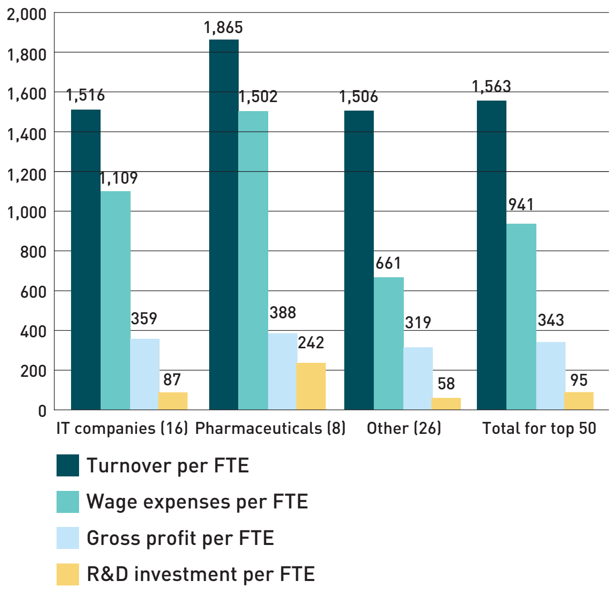
The analysis in this report suggests that the Danish R&D-intensive companies and the largest companies active in R&D have much higher value added than the rest of Danish business and industry. However, it is not possible to draw unequivocal conclusions without analysing the data more closely. It also appears that the Danish R&D-intensive companies are found across the OECD's classifications, encompassing both service and industrial companies and both high technology and medium-high technology companies.

Figure 3: Top 50 R&D investments and employment, 1999



Source: Statistics Denmark and the Danish Institute for Studies in Research and Research Policy.

Figure 4: Top 50, measured by FTEs



Source: Statistics Denmark and the Danish Institute for Studies in Research and Research Policy.

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Box 3: The 50 largest research and development companies

Focus area	No.	R&D investment (DKK million)	Turnover (DKK million)	Gross profit (DKK million)	Payroll (DKK million)	Full-time employees	Avg. full-time employees
IT industries	16	2,313	40,355	29,523	9,543	26,612	1,663
Pharmaceuticals	8	2,774	21,421	17,251	4,452	11,484	1,436
Other:	26	2,236	58,501	25,662	12,394	38,846	1,994
- Other knowledge services	7	608	2,504	1,687	1,067	2,529	361
- Other manufacturing industry	13	973	44,320	17,640	7,589	24,275	1,867
- Engineering industry	6	655	11,677	6,334	3,737	12,042	2,007
Total for top 50	50	7,323	120,276	72,436	26,389	76,942	1,539

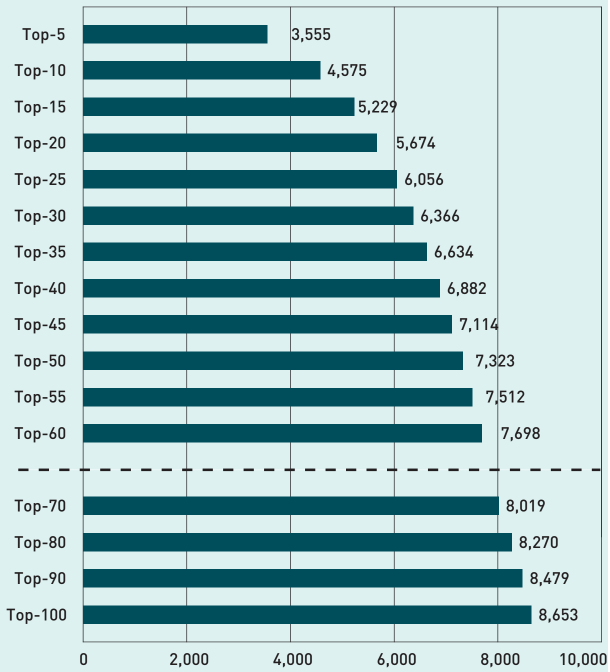
Note: A data set was established as background data for examining the 50 largest R&D companies' share of total R&D in business and industry. The data for research statistics are linked to official register data on turnover, gross profit, employment and so on from Statistics Denmark. In this linkage of data, there arose problems because some companies were difficult to find in the registers, including large R&D companies. They are therefore not included in the new data set. If the top 50 analysis is made on the basis of the original data in the research statistics, the 50 largest R&D companies account for DKK 8.5 billion, or 53 per cent of the total R&D for business and industry.

Total investment in R&D by Danish business and industry in 1999 was DKK 16.1 billion. Almost half of this investment - DKK 7.3 billion - was made by the 50 companies that invest the most in R&D.

The 50 largest R&D companies can be broken down by industry as follows: 16 in the IT industries, 8 in pharmaceuticals and 26 in other industries. None is in the media/ communications focus area. The turnover at the 50 largest companies was DKK 120 billion, and there are 77,000 full-time employees. That is an average of 1,500 employees per company.

Most of the R&D efforts take place at the 10 largest R&D companies. When the 55 largest R&D companies are used instead of the top 50, the change in total R&D investment is only approximately DKK 200 million.

R&D companies, 1999 (DKK million)



Source: Statistics Denmark and the Danish Institute for Studies in Research and Research Policy.

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4.2 Knowledge-intensive companies in Denmark >

- > In 2000, there were 1,819 knowledge-intensive companies in Denmark. That represents 3 per cent of all companies with five or more employees.
- > The knowledge-intensive companies employ two-thirds (40,000) of all knowledge workers (60,000) at Danish companies with more than five employees. Knowledge workers are those with a university degree (Master or PhD).
- > Almost half of all knowledge-intensive companies are found in the knowledge services and pharmaceutical industries.
- > In 2000, 818 companies had been knowledge-intensive companies for at least five years.
- > The 818 stable knowledge-intensive companies had growth in the number of employees of 17.2 per cent. In the same period, the number of knowledge workers at these companies rose by 34 per cent.

>

Introduction

The extent of R&D work is a good indicator of how knowledge-intensive an industry or a company is. But a high level of R&D activity is not sufficient. It is also important that companies can absorb knowledge and use it for innovation. And the volume of research does not tell much about this ability.

There is therefore also a need for an indicator that shows how well companies capture and exploite new knowledge and technology. This section therefore focuses on the companies' employees and their level of education.

Highly educated employees are an important precondition for companies' ability to use new technologies, create new knowledge and improve their financial capacity. For example, highly educated employees can be crucial in enabling a company to develop new products on the basis of university research. This also requires that well-educated employees become part of a network with researchers from knowledge institutions or development employees from other companies.

There are a number of knowledge-intensive companies that hire and retain many employees with a university degree (Master or PhD).

These knowledge workers have great significance for the use of new research knowledge. But that is not all. They have also significance for the companies' innovation process. They might for example, have knowledge about production planning, design, company strategy and management or market research.

Educational level therefore often has much significance for the companies' general ability to acquire new knowledge and convert it into new products, services or improved production processes. Thus, the significance of highly educated employees reaches much further than the industries that are normally associated with a concentration of highly educated employees. More traditional industries such as machinery production, food products and furniture production can also benefit greatly from employees with a university degree (Master or PhD).

It is therefore worthwhile to look more closely at the knowledge-intensive companies.

A company must fulfil two criteria in order to be considered a knowledge-intensive company.

First, it must have at least five knowledge workers, that is, employees with a university degree (Master or PhD). The reason is that this number strengthens the probability that the company has a highly educated, professional environment.

Second, the highly educated employees must represent at least 10 per cent of the company's total staff.

This extra requirement is necessary because many large companies have an administration with at least five employees with a university degree (Master or PhD). The requirement increases the probability that the company has a high level of knowledge intensity.

There are of course other definitions of a knowledge-intensive company. This is only one way of delimiting the concept. The requirements set forth, however, are rather robust when subjected to minor changes. (See also box 1.)

Knowledge-intensive companies in 2000

The 58,000 Danish workplaces (henceforth companies with more than five employees) have 1.4 million employees. There are 61,000 employees with a university degree (Master or PhD).

There are 1,819 knowledge-intensive companies in Denmark This equals 3 per cent of all companies with five or more employees. Nevertheless, the knowledge-intensive companies employ 39,000, or 63 per cent of all knowledge workers in Denmark.

There are 158,000 employees in knowledge-intensive companies, equal to 11 per cent of the employees at companies with five or more employees.

The trend in knowledge-intensive companies from 1995 to 2000

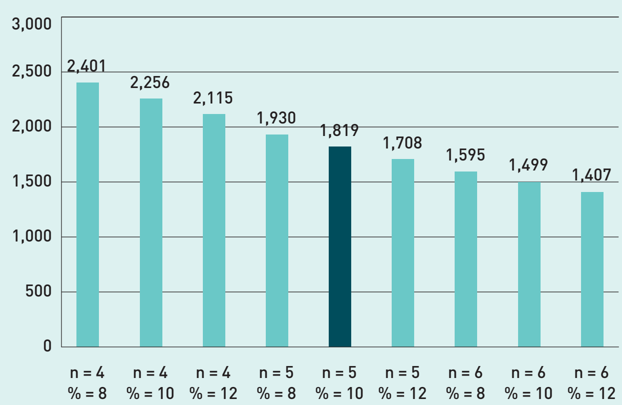
It is relevant to look at the trend in the knowledge-intensive companies. It turns out that many companies became knowledge-intensive in the period 1995-2000. It also turns out that there was strong growth in the number of employees at the knowledge-intensive companies - at the same time that the concentration of knowledge workers grew.

Box 1: Criteria for the selection of knowledge-intensive companies

There are two requirements for a company to be considered a knowledge-intensive company. First, the company must have five knowledge workers, that is, employees with a university degree (Master or PhD). Employees with a Bachelor degree or a medium-cycle higher education, such as those with an engineering diploma, are not counted in this study although they might play a significant role in Danish business and industry. The second requirement is that the employees with this level of education must constitute at least 10 per cent of the total number of employees.

According to these criteria, there were 1,819 knowledge-intensive companies. The selection of the knowledge-intensive companies is relatively robust. That means that the number of knowledge-intensive companies will not change much if one changes the selection criteria.

Criteria for selection of knowledge-intensive companies



Source: Statistics Denmark.

For example, one could stipulate that a company must have either four, five or six highly educated employees (=n). Afterwards, one can vary the requirement for the percentage of the total staff the highly educated employees must constitute. If one sets this requirement at 8, 10 or 12 per cent, the number of knowledge-intensive companies changes only 6.1-6.6 per cent.

Alternatively, one can choose to maintain the percentage of highly educated employees at 8, 10 or 12 per cent and set the number of such employees at four, five or six. With these criteria, the number of knowledge-intensive companies changes 21-24 per cent.

There is a relatively simple explanation for the robust quality of this selection method. There are many small companies in Denmark. Regardless of the limit set for the minimum number of employees, the limit will screen out many small units. In addition, the small companies in many industries have no employees with a university degree (Master or PhD) - or perhaps a single one - so the requirement of five such employees screens out many small companies.

On the other hand, the requirement of a percentage of highly educated employees screens out some of the very large workplaces from the ranks of knowledge-intensive companies. This requirement is a rather strict condition.

In the period 1995 to 2000, the number of knowledge-intensive companies rose by 530 from 1,289 to 1,819, or 41 per cent. At the same time, there was an increase in knowledge-intensive companies as a percentage of total companies in Danish business and industry.

There were 818 stable knowledge-intensive companies in 2000. Stable knowledge-intensive companies are to be understood as companies that have been knowledge-intensive for more than five years.

In the period 1995-2000, 1,000 new knowledge-intensive companies were founded, employing a total of 65,000 persons.

The number of knowledge workers rose from 43,412 to 61,023, or approximately 40 per cent, in the period 1995 to 2000.

>

Box 2: Knowledge-intensive companies in Denmark

Companies and employment

Danish business and industry had a total of 126,370 workplaces (henceforth companies with employees in the private sector) in 2000. Altogether, they employed 1.54 million persons.

A total of 57,969 companies had five or more employees, and they employed almost 1.4 million persons, or 91 per cent of the total employment in the private sector. Of these companies, 1,819 were knowledge-intensive companies and employed a total of 157,789 persons.

There were 1,122 knowledge-intensive companies with five to 50 employees. The number of knowledge-intensive companies with more than 50 employees was 697. This shows that two-thirds of the knowledge-intensive companies are medium-sized companies with 5-50 employees.

Altogether there are 61,023 knowledge workers in companies with more than five employees in the private sector. The number employed in knowledge-intensive companies was 38,688, equal to 63 per cent.

Knowledge workers are most often employed by large companies with more than 50 employees. This is true for two-thirds of all knowledge workers. The trend is even clearer for knowledge-intensive companies, in which three-fourths of knowledge workers work at companies with more than 50 employees.

Knowledge-intensive industries

The five industries that have the most knowledge workers employ a total of 17,014 knowledge workers. That is almost half of the 38,688 knowledge workers who work at knowledge-intensive companies. There are 734 knowledge-intensive companies in the five industries.

Two of the knowledge-intensive industries are among the focus areas that are described in section 4.3. Software development and support consultancy belongs under IT industries, and medical goods plants belong under pharmaceuticals. R&D in natural and technical sciences is listed as a separate category that includes government research institutes, for example. The last two industries are architectural, engineering and other technical consultancy and management consultancy. These are usually designated as knowledge services.

	No. knowledge workers		Company type		Employees broken down by company type	
Top 5 industries for knowledge workers	Other comps.	Knowledge-intensive comps.	Other comps.	Knowledge-intensive comps.	Other comps.	Knowledge-intensive comps.
Architect, engineering, other technical consultancy (7420)	964	5,736	703	265	8,039	17,232
Software development and support consultancy (7220)	927	4,185	643	216	9,551	16,917
R&D in natural and technical sciences (7310)	107	3,105	63	88	609	8,803
Management consulting (7414)	427	1,986	299	143	3,256	6,002
Medical goods plants (2442)	167	2,002	24	22	2,003	8,030
Top 5, total	2,592	17,014	1,732	734	23,458	56,974
Other	19,743	21,674	54,418	1,085	1,215,149	100,815
Total	22,335	38,688	56,150	1,819	1,238,607	157,789

Source: Statistics Denmark, IDA 2000.

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Box 3: Employment in knowledge-intensive companies, 1995-2000

Developments in knowledge-intensive companies from 1995-2000 show that 1,001 new knowledge-intensive companies were founded and they employed 65,667. The trend in the number of knowledge workers shows that there was higher growth in knowledge-intensive companies than in Danish business and industry generally. Knowledge-intensive companies employ more than 63 per cent of all knowledge workers in Denmark.

As far as the trend in the number of companies in the focus areas, media/communications and pharmaceuticals stand at about the same level as the private sector overall, while the number of companies in the IT industries rose sharply from 1,928 to 2,532, or 31 per cent. The number of employees at the 818 stable knowledge-intensive companies grew 13,518, equivalent to 17.2 per cent. By stable knowledge-intensive companies is meant companies that have been knowledge-intensive for more than five years.

Knowledge companies, 1995-2000

	Total companies		Knowledge companies			
	1995	2000	1995	2000	Stable	New companies
The IT industries	1,928	2,532	195	363	109	254
Media/communications	2,544	2,672	68	114	42	72
Pharmaceuticals	748	768	66	82	49	33
Other	49,529	51,997	960	1,260	618	642
Private sector	54,749	57,969	1,289	1,819	818	1,001

Source: Statistics Denmark, IDA 2000.

Employment in knowledge-intensive companies, 1995-2000

	All		Stable			
	1995	2000	1995	2000	Growth	New companies
The IT industries	21,979	39,430	14,566	19,050	4,484	20,380
Media/communications	4,609	7,510	3,291	3,798	507	3,712
Pharmaceuticals	11,482	11,918	10,799	10,256	-543	1,662
Other	66,064	98,931	49,948	59,018	9,070	39,913
Private sector	104,134	157,789	78,604	92,122	13,518	65,667

Source: Statistics Denmark, IDA 2000.

Change in number of knowledge workers, 1995-2000

	Total knowledge workers			Knowledge workers at knowledge-intensive companies		
	1995	2000	Change	1995	2000	Change
The IT industries	6,451	11,588	79.6%	4,545	8,749	92.5%
Media/communications	2,151	3,157	46.8%	865	1,485	71.7%
Pharmaceuticals	3,430	4,018	17.1%	2,354	2,910	23.6%
Other	31,380	42,260	34.7%	16,549	25,544	54.4%
Private sector	43,412	61,023	40.6%	24,313	38,688	59.1%

Source: Statistics Denmark, IDA 2000.

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4.3 Benchmarking the focus areas

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- Pharmaceuticals is the focus area that performs best in the benchmarking.
- The three focus areas - IT industries, media/communications and pharmaceuticals - together account for more than half of the R&D of Danish business and industry, although their turnover amounts to only about 14 per cent of the total turnover of Danish business and industry.
- Half of all of the Danish companies' research man-years take place in the pharmaceuticals or IT industries.
- The profit level in the pharmaceuticals industry, at DKK 600,000 per full-time employee, are twice as high as profits in the rest of Danish business and industry.
- One-fourth of all employees with a university education are employed in the focus areas, which account for only 15 per cent of the total employment in Danish business and industry.
- Of employees in the pharmaceuticals industry, 1.6 per cent hold a PhD, while the corresponding figure for Danish business and industry generally is 0.2.
- Pharmaceuticals is clearly the most innovative of the focus areas measured by the percentage of companies that achieved product or process innovations from 1998 to 2000.
- IT-usage in the focus areas is higher than in Danish business and industry generally.
- The focus areas collectively account for 551, or 31 per cent, of the 1,819 knowledge-intensive companies in Denmark.

>

Introduction

In this section, we focus on selected segments of Danish business and industry. Other industries could have been selected, but these were selected for several reasons. The industries are characterised by a large percentage of highly educated employees, large R&D investments, extensive use of IT, high value added and the development of many new products. Another factor is that a large portion of knowledge-intensive companies are found in the focus areas. Finally, the statistical data on the focus areas are comparable, and there has been substantial development activity in relation to identifying the characteristic products, educational backgrounds and professional positions in these focus areas.

The focus areas differ greatly in size. For example, there are five times as many employees in the IT industries as in pharmaceuticals, and twice as many in the IT industries as in media/communications.

The nature of the products and services the three focus areas create also varies. IT industries consist of manufacturing industries, service industries and wholesale trade. Media/communications consist of service industries and the manufacture of concrete products such as magazines and books. Pharmaceuticals is restricted to manufacturing industries exclusively. These restrictions have been used to balance various factors: first, for the purpose of painting a recognisable picture of what are ordinarily perceived to be companies in the IT, media/communications and pharmaceuticals industries; second, for the purpose of identifying companies with a high knowledge intensity and growth (see the industry delimitations in the section on method).

In recent years, the three focus areas have all experienced bottlenecks and lack of highly educated labour. The tougher competition in the past year, especially in the IT and telecom markets and to a lesser extent in pharmaceuticals and media/communications, has led to unemployment in the shorter term for those with a short-cycle higher education. However, everything indicates that highly educated labour still have favourable employment opportunitiesand the Ministry of Science, Technology and Innovation's projections show that it is very likely there will be a shortage of highly educated labour in the longer term, especially in the health sciences, technical sciences and natural sciences.

In recent years several reports have been issued that have treated the focus areas exclusively or in part. They can be found on the website of the Ministry of Science, Technology and Innovation: *www.vtu.dk.*

In the spring of 2002, a ministerial task force prepared the report "Bio-/sundhed - et nyt partnerskab i vækst" (Biotechnology/health care – a new, growing partnership) and the supplementary report "Biosundhedsarbejdskraft- og uddannelser" (Biotechnology-health care labour and education). These reports take a broader approach to the pharmaceutical and biotechnology industries, since they include wholesale trade, business services and other areas.

The report "IT-arbejdskraft og uddannelser" (IT personnel and education) was published in the summer of 2001. It used the same definition that is used in this report. The report contains a projection of future demand for IT labour and the supply of IT-educated persons. Because of the partial slowdown in the IT and telecom areas, the Ministry of Science, Technology and Innovation will update the figures in the spring of 2003 in collaboration with the IT industry.

In the spring of 2003, an analysis of the supply-demand situation in the media/communications industry is expected to be carried out. It is expected to include electronic media in the industry delimitation to a greater degree than the present report.

A comparison of the focus areas IT, media/communications and pharmaceuticals shows clearly that pharmaceuticals is performing the best on the basis of selected indicators that can be considered representative of the four driving forces in the knowledge society.

Figure 1 shows a benchmarking of the focus areas. For each of the indicators, the focus areas are benchmarked against one another. A rating of 4 means that the focus area performs best in the benchmarking, 3 indicates second-best, and so on.

The IT industries and pharmaceuticals generally perform much better than the rest of Danish business and industry in terms of the indicators of the driving forces in the knowledge society, while media/ communications is at the same level as the rest of business and industry.

As figure 1 shows, pharmaceuticals stands at the top for all the indicators except for knowledge intensity.

It should be noted that the various indicators have not been weighted according to importance, although some of them can be considered a more precise expression of the strength of the industry than others.

Table 1 contains the absolute figures for the benchmarking. The financial key figures such as profit and globalisation show that profits in pharmaceuticals, at DKK 610,000 per full-time employee, is almost twice as high as in the other focus areas and in Danish business and industry generally, and this could derive from large investments in equipment and other things. On the scale of globalisation, pharmaceuticals stands almost four times as high as the other industries.

Table 1 shows that the percentage of employees in pharmaceuticals with a university education is 15.7 per cent. The corresponding figures for the other categories are as follows: IT industries, 13.9 per cent; media/communications, 6.9 per cent; and “other”, 3.7 per cent. Within this educational segment, pharmaceuticals has a significantly higher share of employees with a PhD. Both IT industries and pharmaceuticals have a significantly higher share of employees with a technical sciences, natural sciences, veterinary or agricultural sciences background.

Table 1 also shows that 11 per cent of companies in pharmaceuticals are knowledge-intensive and 14 per cent of companies in the IT industries are knowledge-intensive. In Danish business and industry, 2.4 per cent of companies are knowledge-intensive. Innovative activities are much higher in pharmaceuticals than in the other areas.

Figure 1: Benchmark of focus areas

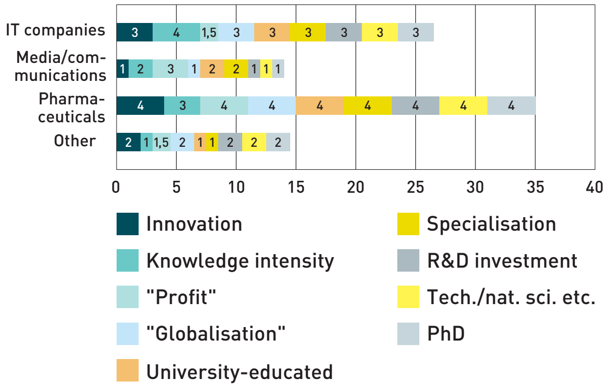


Table1: Benchmarking the focus areas

	IT indu-stries	Media/ comm.	Pharma	Other	Total private sector
PhD	0.3%	0.1%	1.6%	0.2%	0.2%
Tech./nat.	6.5%	0.7%	12.4%	2.1%	2.5%
R&D investment	2.3%	0.1%	9.7%	0.4%	0.7%
“Specialisation”	18.3%	18.0%	24.3%	*	*
University-educated	13.9%	6.3%	15.7%	3.7%	4.7%
“Globalisation”	19.8%	4.2%	74.6%	18.9%	19.6%
“Profit”	3.0	3.3	6.1	3.0	3.1
“Knowledge intensity”	14.3%	4.3%	10.7%	2.4%	3.1%
Innovation	56%	38%	77%	40%	41%

Source: Calculations of the Ministry of Science, Technology and Innovation on the basis of figures from Danish Institute for Studies in Research and Research Policy and Statistics Denmark.

* Specialisations cannot be shown for other industries and private-sector urban industry, since these categories contain many different industries in which is it not meaningful to speak of specialisation. The value is therefore set at 1.0, so the three selected focus areas do not become unjustifiably overvalued.

PhD is PhD educated in percent of employment in 2001

Tech./nat. is employees with a university education I tech./nat.

R&D investment is research and development investment in 1999 in percent of employment in 2001.

Specialisation is core competency in percent of employment in 2001

University-educated is percentage of employment with a university education 2001

Globalisation is export in percent of turnover in 2001

Profit is value creation per FTE minus payroll cost per FTE in 1999 (100.000 Dkr)

Knowledge intensity is percent of knowledge-intensive companies in 2000

Innovation is percentage of companies with product or process innovations

R&D investment in the IT industries and pharmaceuticals is much higher than in the rest of Danish business and industry. Altogether, the three focus areas account for approximately half of all R&D investment in business and industry.

IT industries and pharmaceuticals generally perform much better than the rest of Danish business and industry in the selected indicators, whereas media/communications is at about the same level as the rest of business and industry.

Finances

The three industries that have been selected as focus industries are all relatively small industries. Table 2 shows the size of the various focus areas according to the number of full-time employees and turnover.

The table shows that the IT industries have twice as many full-time employees as media/communications and four times as many as pharmaceuticals. The situation is generally the same for turnover, although media/communications has about one-third the level of IT industries. The table also shows that the IT industries have 96,000 employees and turnover of DKK 192 billion. Media/communications has 48,000 employees and turnover of DKK 65 billion. For pharmaceuticals, the figures are 21,000 employees and DKK 41 billion in turnover.

The ownership status of the three focus areas varies to some extent. Table 2 shows that about 30 per cent of companies in media/communications and the IT industries are private limited companies or public limited companies, whereas the figure is 56 per cent for pharmaceuticals. The difference might indicate that there is a greater need for external capital in pharmaceuticals and that the investments are riskier.

In comparing the focus areas with Danish business and industry as a whole (see table 2), we see that the IT industries account for 9 per cent of total employment in the private sector, while media/communications accounts for 3 per cent and pharmaceuticals for 2 per cent.

The focus areas became more significant in the period from 1995 to 1999. Table 2 shows that the number of full-time employees in Danish business and industry generally rose 6.2 per cent in the period, while the number in the IT industries rose 29 per cent, the number in media/communications rose 10.4, and the number in pharmaceuticals rose 2.7 per cent.

Table 2: The economic significance of the focus areas

	Full-time employees in 1999	Growth in full-time employees from 1995 to 1999	Turnover in 2001 (DKK million)	Percentage of employees	No. companies in 1999	No. private limited or public limited companies	% private limited or public limited companies
The IT industries	96,241	29	191,742	8.7%	14,132	4,304	30
Media/communications	47,602	10.4	65,153	4.3%	13,106	3,541	27
Pharmaceuticals	21,094	2.7	40,926	1.9%	495	279	56
Other industries	945,988	6.2	1,850,251	86.1%	208,415	51,698	25
Private sector	1,110,925	8.0	2,148,072	100%	236,148	59,822	25

Source: Statistics Denmark, firmastatistikken (company statistics).

Table 3 shows value added, payroll costs and profit per full-time employee in 1999. Value added, which is net turnover less cost of goods sold, is an indication of profit in business and industry that can be considered in relation to payroll costs and return on the rest of the production apparatus.

Table 3 also shows that the payroll cost per full-time employee were generally the same for the three focus areas, although it was somewhat higher in the IT industries. In all three areas, this indicator was more than 20 per cent higher than the average for the private sector as a whole, which could be related to the high educational level and consequently higher salary level in the focus areas.

There is a large variation in value added per full-time employee in the focus areas. In the IT industries and media/communications, the level is about DKK 650,000, or nearly 100,000 above the average for the private sector. On the other hand, it is about DKK 300,000 below the level of pharmaceuticals, and this difference increases in the profit indicator. Pharmaceuticals, with a profit of DKK 600,000, stands much higher than the others, which show a profit of about DKK 300,000. This might indicate that the area either has large investment expenses or is more productive.

Table 3: Payroll cost and value added per full-time employee in 1999 (DKK 1,000)

	Value creation per FTE	Payroll cost per FTE	"Profit"*
The IT industries	651	351	300
Media/communications	646	319	327
Pharmaceuticals	938	330	608
Other industries	564	265	299
Private sector	581	276	305

Source: Statistics Denmark, firmastatistikken (company statistics).

* Profit is value creation less salary.

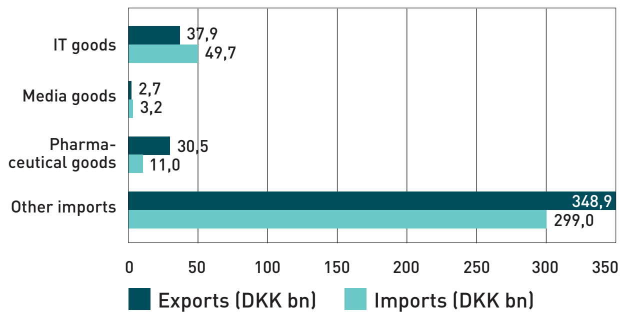
An important indicator of the significance of the focus areas for Denmark is the competitiveness of their products in the international markets. The trade balance for the products of the IT industries, media/communications and pharmaceuticals might give an indication of their competitiveness. It is important to keep in mind that figure 2 concerns only physical products, and this means that consultancy services and the like are not included in the count. This has particular influence on the IT industries' figures because in Denmark most of these companies are consultancy firms. To some extent, this is also the case for media/communications companies.

The value of exports of goods from the IT industries, media/communications and pharmaceuticals together amount to DKK 71.2 billion, nearly 17 per cent of the total value of goods exports, DKK 420 billion, in 2001. The IT industries, at 9 per cent, contributed the largest share, pharmaceuticals accounted for 7 per cent and media/communications for 1 per cent. The most remarkable figure is the share of goods from pharmaceuticals, because it is the smallest industry.

The value of imports of IT goods was DKK 49.7 billion, or nearly 14 per cent of the total value of goods imported to Denmark (DKK 362.9 billion), while pharmaceutical goods, at DKK 11 billion, represented only 3 per cent. The value of goods from media/communications companies was again the lowest, at less than 1 per cent of total imports in 2001.

Figure 2 shows, that if one compares the amounts of exports and imports, there is a deficit in the trade balance for IT goods of DKK 13 billion, a deficit for media/communications goods of about DKK 0.5 billion, and a surplus of DKK 19.5 billion for pharmaceutical goods. The total trade balance shows a deficit of DKK 50 billion, while the total trade balance for the three focus areas was a surplus of approximately DKK 7.2 billion.

Figure 2: Import and export of goods, 2001 (DKK billion)

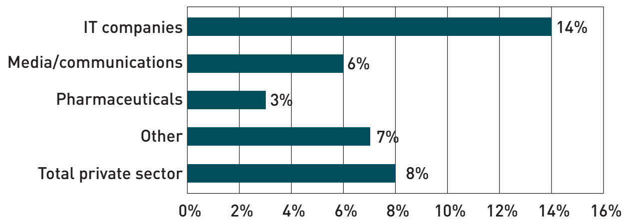


Source: Statistics Denmark,
Udenrigshandelsstatistik (Foreign trade statistics).

* Note: Foreign trade data are based on total import and export of physical goods.

One indication of the degree of dynamism in the focus areas is the establishment rate, that is, new companies as a percentage of the total number of companies in each of the focus areas (1999). As figure 3 shows, the establishment rate of 14 per cent in the IT industries is much higher than in the other industries. At 6 per cent, media/communications stands just under the average for the private sector and "other" at 8 per cent and 7 per cent respectively. Pharmaceuticals is clearly the lowest, with an establishment rate of 3 per cent, which can possibly be explained by the rather large investments involved in the launch of new companies.

Figure 3: Company establishment rate, 1999



Source: Statistics Denmark, Statistik over tilgange af nye virksomheder (Statistics on the founding of new companies).

Education

Turning to the educational characteristics of the focus areas, one can see in table 4 that pharmaceuticals, at 15.7 per cent, has the largest percentage of employees with a university education. In the IT industries, the figure is 13.9 per cent, and in media/communications, it is as low as 6.3 per cent.

Table 4 also shows that in the IT industries there are 36,062 IT positions, 21,133 employees with an IT education, and 12,344 employees who both have an IT education and fill an IT position. In media/communications, there are 17,777 media/communications positions, 16,443 employees with a media/communications education, and 9,195 employees who both have a media/communications education and fill a media/communications position. In pharmaceuticals, there are 4,419 pharmaceuticals positions, 4,667 employees with a pharmaceuticals education, and 2,978 employees who both have a pharmaceuticals education and fill a pharmaceuticals position.

Table 4: Educational background, 2001

	Employees	University-educated	%	Industry-specific position	Industry-specific education	Core competency*	PhD	PhDs as % of employees
The IT industries	115,594	16,081	13.9	36,062	21,133	12,344	373	0.32
Media/communications	91,117	5,741	6.3	17,777	16,443	9,195	61	0.07
Pharmaceuticals	19,227	3,024	15.7	4,419	4,667	2,978	306	1.59
Other industries	1,312,238	72,790	5.5				2,218	0.17
Total Private Sector	1,538,176	97,636	6.3				2,958	0.19

* Core competency means that the employee has both an industry-specific education and holds an industry-specific position.

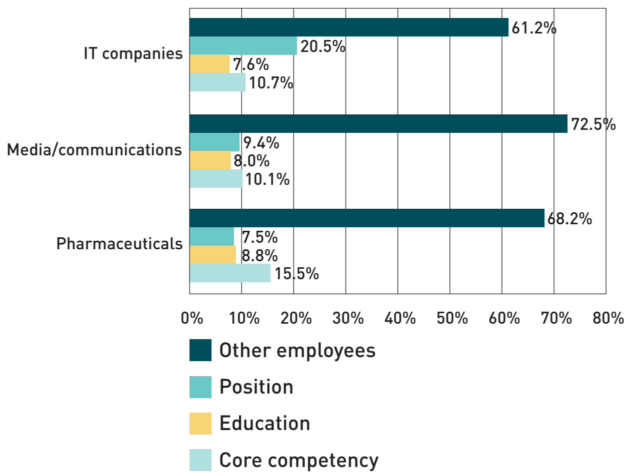
Source: Statistics Denmark, uddannelsesstatistikken (education statistics).

Regarding the employees with PhD degrees, the table shows that 0.32 per cent of employees in the IT industries and 0.07 per cent of employees in media/communications have a PhD. In pharmaceuticals the percentage is much higher, at 1.6 per cent of employees.

Figure 4 shows that, in the IT industries, 10.7 per cent of employees have an industry-specific core competency; that is, they have an IT position and an IT education. In media/communications, 10.1 per cent of employees have an industry-specific core competency, and in pharmaceuticals, the figure is 15.5 per cent.

In addition, the chart shows that 18.3 per cent of the employees in the IT industries have an IT education (education plus core competency) and 31.2 per cent fill an IT position (position plus core competency). In media/communications, 18.1 per cent of the employees have a media/communications education, and 19.5 per cent fill a media/communications position. In pharmaceuticals, 16.3 per cent of the employees have a pharmaceuticals education, and 24 per cent fill a pharmaceuticals position.

Figure 4: The competencies of employees, 2002



Source: Statistics Denmark, Uddannelsesstatistik (Education statistics).

Table 5: University-educated employees by main area, 2001 (%)

	Nat.	Tech.	Health	Soc.	Hum.	Agric./vet.	Other	Total %
The IT industries	13.6	31.7	0.5	39.7	12.9	0.7	0.9	16,081
Media/communications	4.2	5.1	1.0	44.6	40.8	0.8	3.5	5,741
Pharmaceuticals	16.5	25.0	33.9	11.8	6.7	3.7	2.4	3,024
Other	7.5	20.9	3.8	41.7	15.9	6.2	3.9	72,790
Total Private Sector	8.6	21.9	4.1	40.6	16.6	4.9	3.3	97,636
Total %	8,398	21,388	3,965	39,654	16,231	4,771	3,229	

Source: Statistics Denmark, uddannelsesstatistikken (education statistics).

Taking a closer look at the employees with a university education (that is, a Bachelor, Candidatus (Master) or PhD degree), we see further variations within the focus areas. Table 5 shows that the IT industries have the most employees with technical and social sciences backgrounds, but also many with natural sciences and humanities backgrounds. In media/communications, the large majority of employees have a humanistic or social sciences background. In pharmaceuticals, most have a health sciences education.

The table also shows that social sciences and humanistic backgrounds dominate media/ communications. The breakdown by educational background is much different in pharmaceuticals. The percentage of those with health sciences educations is many times greater than the corresponding figures in the other focus areas as well as the categories “other” and “the private sector”. Pharmaceuticals is also notable in having a much lower percentage of employees with a social sciences education.

Research

Companies’ total investments in R&D in 1999 were approximately DKK 16 billion. The funds were used mostly for operating expenses (payroll and other operating expenses), while investment expenditure amounted to approximately 13 per cent. The three focus areas collectively accounted for approximately half of the investment in R&D in the private sector, with investments of DKK 8.5 billion.

The large majority of R&D financing was done with the companies’ own funds. It was not possible to make comparisons across all three focus areas, so only the IT industries and pharmaceuticals are compared with the rest of the private sector.

Table 6: Breakdown of R&D expenditure by own company, 1999 (DKK million)

	Total operating exp.	Total investment exp.	Total R&D exp.
The IT industries	4,204	294	4,498
Media/communications	40	3	43
Pharmaceuticals	2,996	955	3,952
Other	6,709	852	7,561
Total private Sector	13,949	2,105	16,054

Source: Erhvervslivets forskningsstatistik (Private sector research statistics), 1999.

Foreign investment in Danish R&D amounted to about 5 per cent of the total investment, or almost DKK 1 billion. In 1999, the IT industries attracted almost one-third of these funds. About one-fourth of the funds from abroad originated from EU funds, and the remaining three-fourths came from other foreign financing.

The breakdown of R&D man-years shows that there is a larger percentage of academic personnel (AP) in pharmaceuticals and the IT industries than in media/communications and the rest of the private sector.

Total man-years were approximately 21,000, and the IT industries and pharmaceuticals accounted for about half of this number, with 6,257 and 3,688 respectively. The figure is lower for media/communications, which had a total of 106 man-years, or only approximately 0.5 per cent of total R&D man-years.

Innovation

There are clear differences among the companies in the focus areas as far as innovation is concerned. The innovation figures are all based on companies with more than 10 employees. In pharmaceuticals, 77 per cent of the companies achieved product or process innovations during the period 1998-2000, and this is considerably more than the level in the IT industries and especially media/communications. The figures for the IT industries and media/communications were 56 per cent and 38 per cent respectively. For media/communications, the percentage lies just under the average for the rest of the private sector.

Consequently, pharmaceuticals is by far the most innovative industry as measured by the percentage of companies that have achieved product or process innovations.

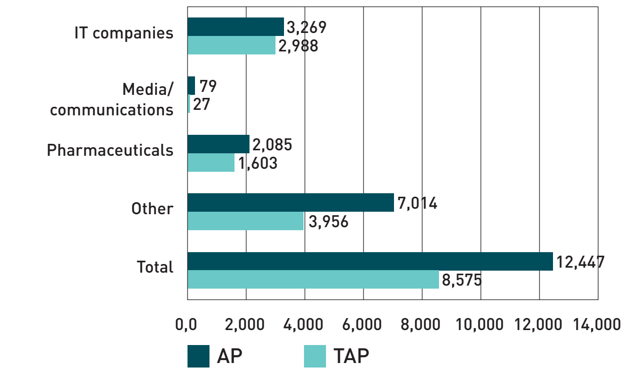
Table 7: R&D funding from abroad, 1999 (DKK million)

	EU funding	Other foreign financing	Total
The IT industries	31	262	293
Pharmaceuticals	2	64	67
Other	163	440	603
Total Private Sector	196	767	963

Source: Erhvervslivets forskningsstatistik (private sector research statistics), 1999.

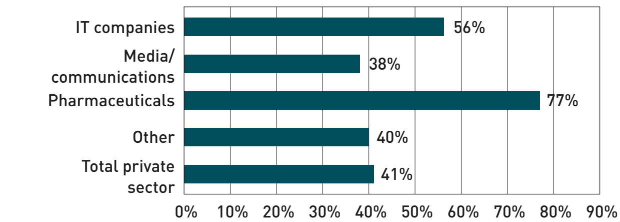
Note: For discretionary reasons, media/communications is included under "Other".

Figure 5: Breakdown of R&D man-years, 1999



Source: Erhvervslivets forskningsstatistik (Private sector research statistics), 1999.

Figure 6: Percentage of companies with product or process innovations



Source: The Danish Institute for Studies in Research and Research Policy, 2002.

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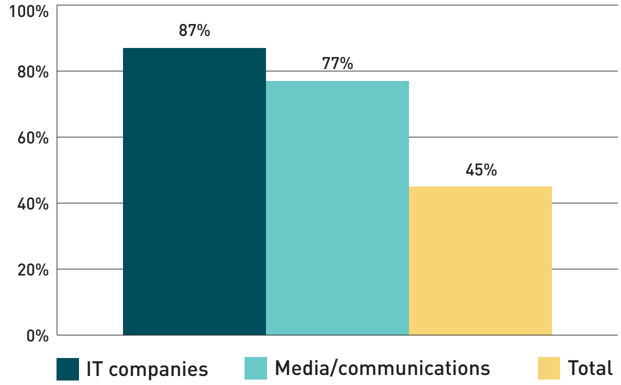
IT usage

The focus areas have extensive access to the Internet. For the private sector in general, 45 per cent of companies have a high-speed Internet connection (see figure 7). For the IT industries, 87 per cent of companies have a high-speed connection, and for media/communications, 77 per cent have a high-speed connection. There is no information on this issue for pharmaceuticals.

In considering how the focus areas use IT, the extent of their e-commerce, including whether the companies receive orders via the Internet, is a useful indicator. Figure 8 shows that 29 per cent of companies in the IT industries received orders via the Internet in 2001, and 25 of per cent of media/communications companies did so. The average for Danish companies was 23 per cent.

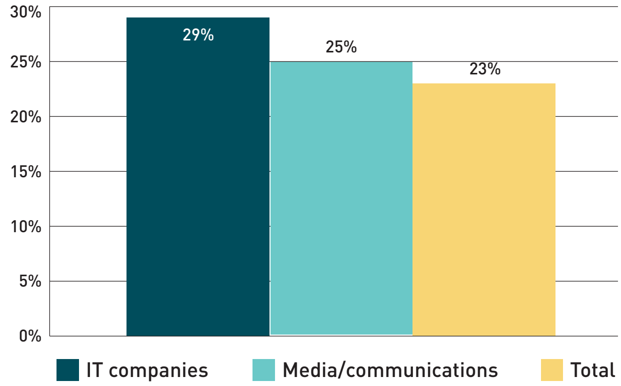
Figure 7: High-speed connection to the Internet, 2001, percentage of companies with Internet access



Source: Statistics Denmark, Danske virksomheders brug af IT (Danish businesses' use of IT), 2001.

Note: By high-speed connection is meant broadband, ADSL or another connection that is faster than an analogue modem or ISDN.

Figure 8: Companies that receive orders by the Internet, 2001, percentage of companies with Internet access



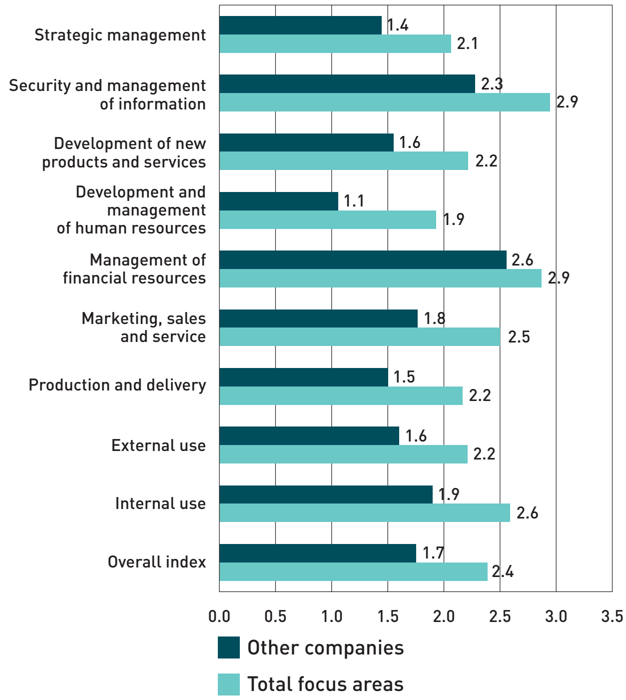
Source: Statistics Denmark, Danske virksomheders brug af IT (Danish businesses' use of IT), 2001.

In 2002 the Ministry of Science, Technology and Innovation developed an IT index with which it is possible to outline companies' use of IT in relation to their business processes, such as production, development, management and marketing. The starting point for the IT index was that it is not enough to have access to the Internet and have a website. It is also crucial that the technologies are used efficiently to support and create coherence in companies' business processes and development.

In an index with a scale from 1 to 4, the average score for IT use in the focus areas is generally much higher than the scores for other companies in Danish business and industry. A high score indicates that a company's business processes are supported by IT to a great extent. Figure 9 shows that the average score for the focus areas is about 2.4, while the score for "other" companies is 1.7.

Companies in the focus areas thus have relatively high IT use, both in terms of IT directed toward internal business processes and IT used in support of external processes and thus their interaction with other companies, such as customers, subcontractors and orderers. This is especially important in marketing and sales, in which many companies in the focus areas service customers with so-called expert databases in connection with solutions to customers' technical problems, for example. Another area in which the focus areas are ahead of other companies in IT use is the development and management of human resources.

Figure 9: Use of IT by companies in relation to business area (IT index)



Source: Statistics Denmark and Ministry of Science, Technology and Innovation.

Index score: min. = 0; max. = 4.

Knowledge-intensive companies

The percentage of knowledge-intensive companies in all three focus areas is greater than the average for the rest of the private sector. At 14.3 per cent, the IT industries are the focus area with the largest share of knowledge-intensive companies. The share of knowledge-intensive companies in pharmaceuticals is more than four times higher than the average in the rest of Danish business and industry. The focus area that is closest to the overall level is media/ communications, which at 4.3 per cent is 1.2 percentage points higher than the overall level.

The trend from 1995 to 2000 shows that the percentage of knowledge-intensive companies is rising in the three focus areas and also in the private sector. Table 8 shows that the increase is substantially more pronounced in the focus areas.

Figure 10 shows that 20 per cent of knowledge-intensive companies are found in the IT industries, 6 per cent are found in media/communications, and 5 per cent are found in pharmaceuticals. Altogether, there are 559 knowledge-intensive companies in the focus areas. This equals 30.7 per cent of all knowledge-intensive companies.

Figure 11 shows that the IT industries employ 8,749 knowledge workers in knowledge-intensive companies. That equals 76 per cent of all knowledge workers in the IT industries.

In media/communications, there were 1,485 knowledge workers at knowledge-intensive companies. This equals 47 per cent of all knowledge workers.

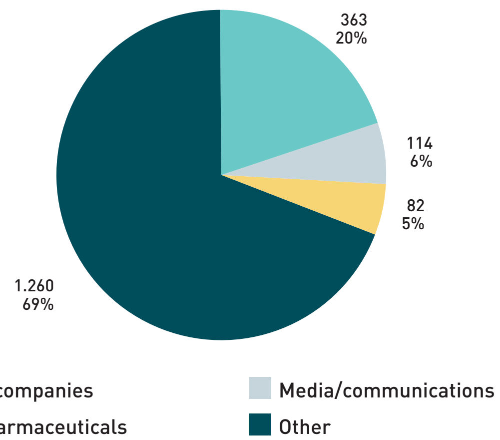
Pharmaceuticals has 2,910 knowledge workers in knowledge-intensive companies, or 72 per cent. In comparison with the rest of Danish business and industry, in which 60 per cent of knowledge workers work at knowledge-intensive companies, the IT industries and pharmaceuticals have a higher concentration of knowledge workers. Media/ communications, on the other hand, has a lower concentration.

Table 8: Percentages of knowledge-intensive companies, 1995-2000

	1995			2000		
	Knowledge-intensive	Total	%	Knowledge-intensive	Total	%
The IT industries	195	1,928	10.1	363	2,532	14.3
Media/ communications	68	2,544	2.7	114	2,672	4.3
Pharmaceuticals	66	748	8.8	82	768	10.7
Other	960	49,529	1.9	1,260	51,997	2.4
Total Private Sector	1,289	54,749	2.4	1,819	57,969	3.1

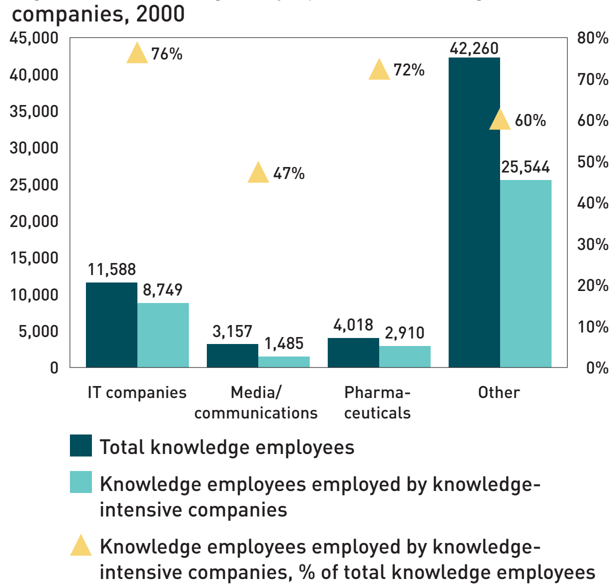
Source: Statistics Denmark, IDA.

Figure 10: The 1,819 knowledge-intensive companies by focus area, 2000



Source: Statistics Denmark, IDA.

Figure 11: Knowledge employees in knowledge-intensive companies, 2000



Source: Statistics Denmark, IDA.

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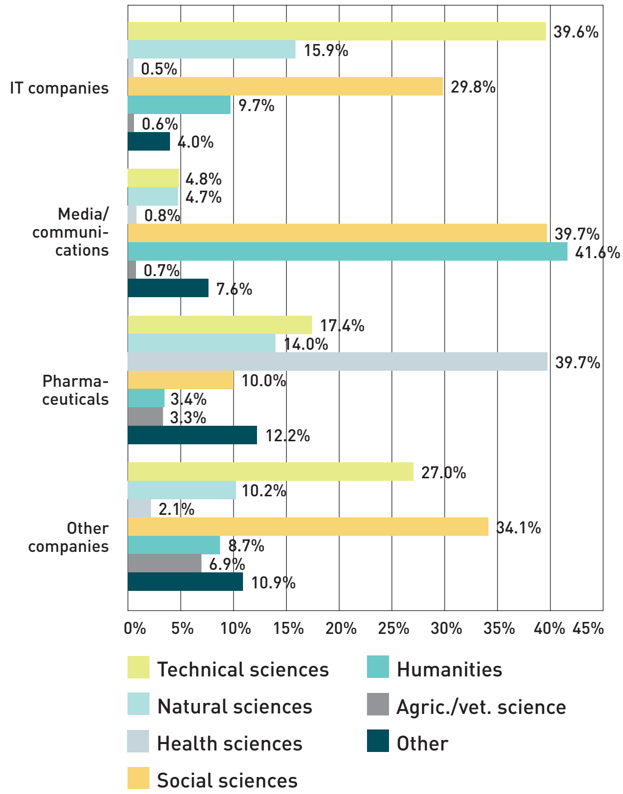
Most of the 8,749 knowledge workers in knowledge-intensive companies in the IT industries have a technical or social sciences education. Almost 40 per cent of employees have a technical education, and 30 per cent have a social sciences education.

For the 1,485 knowledge workers in media/communications, the picture looks rather different. Here most - a full 80 per cent - have a humanities or social sciences education.

Health sciences is by far the most common education for the 2,910 knowledge workers in pharmaceuticals; 40 per cent have this background.

Most of the 25,544 knowledge workers in the rest of Danish business and industry have studied social sciences or technical sciences.

Figure 12: Percentage breakdown of knowledge employees by educational background, 2000



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5. Method

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General

The definition of “the private sector” is industry codes 15-37 (Industry), 45 (Construction companies), 50-52 (Trade and repair companies), 55 (Hotel and restaurant companies), 60-64 (Transport companies and the like), 65-67 (Financial institutions, financing companies and insurance companies), 70-74 (Business service and the like), 92 (Entertainment, culture and sport), 93 (Other service companies), 804100 (Driving schools), 804290 (Teaching), 852000 (Veterinarians) and 980000 (unknown). This delimitation includes industries in the private sector with market-directed activities and is the most realistic foundation for comparison from the perspective of knowledge, since the primary industries are omitted.

The category “Other” is the private sector except for the three focus areas: IT industries, media/ communications and pharmaceuticals.

In this report, a number of Danish researchers’ contributions are presented in separate boxes to illuminating the knowledge society. The results of the research are presented in separate fact boxes to underscore that the researchers invited were not involved in the preparation of the other parts of this report. Thus, the selection of researchers has had no bearing on the content and form of the report.

Chapter 2

This chapter is a summary theoretical description of research, education, innovation and the significance of IT for economic growth in society. It is based on research projects domestically and internationally that have investigated these relationships. The selection criteria were that the results must be recognised, current and, as far as possible, based on Danish conditions. The chapter is based on a report from Oxford Research from October 2002.

Chapter 3

The results of this chapter are statistical time series and more detailed pictures of the data for the most recent accessible year that show the status of research, education, innovation and IT. The primary sources are Statistics Denmark, Danish Institute for Studies in Research and Research Policy, The Ministry of Science, Technology and Innovation, The Danish IT and Telecom Agency, the OECD and EUROSTAT.

Denmark’s international status is presented by comparisons with similarly small, highly educated knowledge societies: Sweden, Norway, Finland and the Netherlands. In addition, Denmark is benchmarked against the averages for the EU and the OECD as well as, from a wider EU perspective, against the USA and Japan. In the individual tables, there are deviations in the lists of countries compared, either because of the absence of data or because other countries are relevant to the comparison in question.

Section 3.1

This section uses statistics prepared by the Danish Institute for Studies in Research and Research Policy. Three sets of statistics in particular were used extensively:

> “Erhvervslivets forskning og udviklingsarbejde” (Research and development work in the private sector).
> “Forskning og udviklingsarbejde i sundhedssektoren” (Research and development work in the health care sector).
> “Offentligt forskningsbudget” (The public research budget).

All the statistics were prepared according to the OECD’s guidelines, which appear in the Frascati manual (“The Measurement of Scientific and Technological Activities. Proposed Standard Practice for Surveys of Research and Experimental Development”, Frascati Manual 2002, OECD.)

“Forskning og udviklingsarbejde i den offentlige sektor” (Research and development work in the public sector) and “Erhvervslivets forskning og udviklingsarbejde” (Research and development work in the private sector) are both retrospective, as they are “R&D accounts” that measure the actual R&D activities in a given period and the expenses that were associated with these activities. These two sets of statistics together map out the overall R&D work conducted in Denmark.

On the other hand, the public research budget is based on appropriation figures and budgets and is thus forward-looking. The public research budget shows the intentions of the grantee for individual R&D appropriations, but it does not give any indication of the actual activities and the actual use in R&D. On the other hand, the public research budget gives a current overview of how the public R&D appropriations are distributed according to research purpose, institution type and so on.

It should also be noted that the three statistical publications are all based on the input side of the R&D process. That is, they measure appropriations, expenses and man-years that are either used on R&D work (the statistics) or are planned for use in R&D (budgeted). Neither of the three publications therefore illuminates the actual results that come from the research carried out. For this, output-based statistics are required, for example, in the form of calculations of the number of research publications, the number of PhDs and doctoral degrees, the number of patents and so on. This does not illuminate the effect of R&D either; here measures such as the number of citations, spin-offs, innovations and approved patents could be used.

Section 3.2
The statistics for Bachelor degrees and Candidatus degrees (Master degrees) are based on Statistics Denmark's integrated student register. The latest enrolment figures are supplemented with figures from the Coordinated Registration System. PhD statistics are based on the PhD register of the Ministry of Science, Technology and Innovation.

The educational time series in many cases are based on the adaptation of basic data from Statistics Denmark's integrated student register, via the Ministry of Education's statistical modules. In many cases, the time series, especially for the educational area, were generated 20 years back, until 1980, for the purpose of illustrating the large fluctuations that have taken place in young people's educational preferences.

When educational data are linked to employment data, the time series usually begin in the 1990s because of data validity.

Section 3.3
In the CIS3 study, innovation covers both product and process innovation, that is, activities whose purpose is to introduce new or significantly improved products (goods or services) on the market or introduce new or significantly improved processes in the company. Innovation must also be based on the results of new technological developments, new combinations of existing technologies or the use of other knowledge gathered in the company.

A good or service is an innovative product if it is either new or significantly improved in its fundamental characteristics, technical specifications, built-in software, intangible components, applications or user-friendliness. The innovation must be a new product or service for the company. It does not necessarily need to be new for the market. Whether the innovation was developed by the company itself or another company has no significance. Changes of purely aesthetic factors or pure resale of innovations that are produced exclusively by other companies are not included in this study as innovations.

Regarding process innovation, in this study a process is considered innovative when the result is new or significantly improved production technology, concepts for services or concepts for the distribution of products. The result must be significant in regard to productivity, improvement in the quality of a product or service, or savings on production and distribution costs. The innovation must be a new process for the company. The company does not necessarily need to be the first one to introduce the new or modified process. Whether the innovation was developed by the company itself or another company has no significance. Purely organisational or management modifications are not included as innovations in this study.

The response rate for the CIS3 study was 30 per cent, but the estimate of the responses on the basis of responses from 1999 and 2001 increased the response rate to 43 per cent, which became the final response rate. The survey was addressed to 5,133 companies. Of this number, 204 companies were declared invalid for various reasons (they no longer existed or belonged to industries that were not included in the random samples and so on).

Section 3.4
Figures from Statistics Denmark on the use of IT by the population were gathered in voluntary telephone interviews involving about 12,000 respondents annually.

The figures on the use of the Internet were gathered by Vilstrup Interactive and Netcoders, which

followed the behaviour of 3,742 test subjects on the Internet by means of an observation method.
The behaviour on the Internet was registered in a total of eight content categories: news, art and culture, holiday and leisure, people and health, business and industry, sex and eroticism, IT and technology and public websites.

The observation methodology involves the use of the Repcore technology, which is based on an identification technique in which the identification of the individual users is based on a combination of the user's current IP number, combined with a unique user ID that is generated by Repcore and placed on the user's hard drive for six months. The placement occurs the first time the user-respondent visits a website on which a Repcore counter has been installed to measure traffic. Thus, the system is dynamic and is adjusted to the development of websites and user behaviour on an ongoing basis.

The study "Danske virksomheders brug af it" (Danish companies' use of IT), 2001, from Statistics Denmark.

Companies' responses were gathered in November 2001 in a voluntary questionnaire-based survey. The questionnaire was filled out by 3,327 companies with at least five employees in more than half of Danish business and industry. These figures also laid the groundwork for the OECD's calculations of Internet sales. A large amount of register data from Statistics Denmark was also included. The sources are shown beneath the charts and tables.

The study "Den offentlige sektors brug af it" (The public sector's use of IT), 2002, comes from Statistics Denmark. The responses were gathered in a voluntary questionnaire-based survey among public authorities (at the central government, county and local authority level).

Section 4.1
The study of R&D in chapter 4 was made on the basis of a combination of R&D data from the Danish Institute for Studies in Research and Research Policy and from Statistics Denmark's Firmastatistik (Company statistics).

The OECD uses aggregated industry categories when it classifies all the companies in the OECD countries according to the degree of R&D intensity. By classifying the individual industries on the basis of R&D expenditure as a percentage of value added and R&D expenditure as a percentage of production, it breaks the companies down into three segments: medium-low-technology, low-technology, medium-high technology and high technology industries. In this report, we have drawn conclusions only in relation to the two latter segments and companies that belong under knowledge services (see OECD, STI Scorecard 2001, p. 138, among other sources).

Table 1: Identification of companies in OECD approach

Industry type	
Knowledge service	**Industry code**
IT consultancy	72
Research and development	73
Legal, accounting, opinion surveys, market research and management consulting	74.11-74.14
Architecture, engineering and other technical consultancy	74.2
Technical testing and control	74.3
Advertising and marketing	74.4
Interior design, industrial design, conferences and exhibitions	74.84
High-technology industries	
Pharmaceutical raw materials and medical plants	24.4
IT industry	30
Telecommunications industry	32
Manufacture of medical and surgical equipment	33
Aircraft plants and workshops	35.3
Medium-high-technology industries	
Chemicals	24 (ex.24.4)
Engineering	29
Electronics	31
Automotive	34
Rail	35.2
Motorcycle and bicycle industry	35.4
Manufacture of other means of transport	35.5

Source: Statistics Denmark (industry designations adapted by the Ministry of Science, Technology and Innovation).

In the R&D analysis, the concept of gross profit is used for company value added. The concept comes from the new company statistics, and, as value added, it is defined as turnover less cost of goods sold. The starting point is the study of R&D in Danish business and industry made by the Danish Institute for Studies in Research and Research Policy in 1999. This report is an interview survey involving a segment of companies. In compiling the study, the Danish Institute for Studies in Research and Research Policy received an extract about the companies (the legal units) from the Centralised Civil Register.

In some cases, the study by the Danish Institute for Studies in Research and Research Policy included information that did not concern the legal unit taken from Erhvervsregisteret (the Industry register) but rather the entire group. We have therefore investigated whether the information from the two sources - the study by the Danish Institute for Studies in Research and Research Policy and Statistics Denmark's information - concern the same unit.

When there was much uncertainty about whether there is a coincidence between the unit included in the questionnaire study by the Danish Institute for Studies in Research and Research Policy and the unit that is associated with the CVR number (company registration number) in the register in Statistics Denmark, the unit was subjected to additional individual tests.

The data were analysed for deviations between the figures for the number of employees in the study by Danish Institute for Studies in Research and Research Policy and Statistics Denmark's figures for employees and for differences between turnover figures from various sources. Units for which employment data were not disclosed were also investigated.

In cases in which there is uncertainty about the unit to which the response applies, we investigated whether the legal unit in the study by the Danish Institute for Studies in Research and Research Policy was part of a corporate group and whether the response applied to the entire group. If this was not the case, the unit was accepted. If it cannot be determined with probability that the response applies to the entire group, the unit is screened out.

The study by the Danish Institute for Studies in Research and Research Policy covers 3,261 companies. The present study is restricted to the private sector. This restriction removed 50 units from the data material. In combining the data with the register data, 68 units were screened out in the preliminary validation, 5 were not found in company statistics, and 68 were screened out in the final validation. A total of 233 units was screened out.

A total of 3,028 companies remained. The companies that did not belong under the private sector represent a weighted DKK 79 million in R&D expenditure. The screened-out companies represent weighted R&D expenditure of DKK 2,303 million. A total of DKK 2,382 million in R&D expenditure was thus removed. The screened-out companies represent weighted employment of approximately 111,000 man-years.

The method used in the study by the Danish Institute for Studies in Research and Research Policy was designed to cover the entire manufacturing industry and selected parts of the rest of Danish business and industry. All companies in the selected industries over a certain size, measured by the number of employees ("large companies"), were addressed. The size limitation varied from industry to industry and ranged from six to 100 employees. In addition, random samples were taken from 25 per cent of the remaining small companies with more than five employees in the manufacturing industry.

At the micro level, companies that were selected from the category of large companies were assigned a weighting that compensated for the removal. The small companies in the random sample in the manufacturing industry were also assigned a weighting at the micro level that both compensates for the removal and is used to calculate the total level. Thus, there is a listing at the total level for the entire manufacturing industry and for the various groups in the other industries broken down by size (see Erhvervslivets forskning og udviklingsarbejde" [Research and development work in Danish business and industry], p. 52).

In the combination of the register data from the company statistics, the variables used are weighted according to the weightings at the micro level used in the study, for both 1999 and 2000. This means, for example, that the turnover in the manufacturing industry is listed at the total level for the manufacturing industry, while the turnover for companies in an industry is listed at the total level for the group based on size that was selected for the industry, for example companies with more than 100 employees. Thus, the total figure in the study for turnover, for example, becomes lower than the total turnover in Danish business and industry.

We have made a test of how well the listed figures for employment and turnover match the corresponding figures for the segment of Danish business and industry that the study covers. In the company statistics for 1999, the same industry segments that the R&D study covers were selected.

Section 4.2
In section 4.2, “Knowledge-intensive companies in Denmark,” we use a definition of a knowledge-intensive company that is based exclusively on statistical material. A knowledge-intensive company is defined as a workplace where there at least five employees with a university degree (Master or PhD) and these employees constitute at least 10 per cent of all employees at the company.

This delimitation implies that for a company to be considered a knowledge-intensive company, there must be a likelihood of a knowledge environment at the company. That is, an environment that gives an opportunity to use knowledge in an interaction between several persons. The definition implies that this environment must grow in step with the number of employees at the company.

It should also be noted that persons with a university degree are defined as persons who have completed a Candidatus degree (Master degree) or a PhD. Holders of Bachelor degrees are thus not included in this category.

The data for the section were taken from the Integrerede Database for Arbejdsmarkedsforskning (Integrated database for labour market research, designated as “IDA” in source references; you can read more about IDA at www.dst.dk/forskning).

IDA
IDA is an integration of Registerbaserede Arbejdsstyrkestatistik (Register-based labour force statistics, designated as “RAS”), Erhvervsbeskæftigelsen (arbejdsstedsstatistik) (Employment in business and industry [workplace statistics]) and Uddannelsesstatistikken (Educational statistics), among other sources. IDA contains the entire population, all employees and all workplaces as well as linkages between employees and workplaces. The employment situation of every individual is determined annually (at the end of November) that is, the workplace of each person is determined. It is therefore possible to characterise workplaces on the basis of information about employees, as was done in section 4.2. Here the employees’ educational background is used to identify knowledge-intensive companies.

The company unit in IDA is the workplace. A workplace is defined as an organisationally limited part of a company that is located at one address and produces one - or predominately one - type of goods and services.

It is not possible to link employees to a workplace when the employees do not work at any of the company’s registered workplaces but rather work out of their residence or carry out their work near their residence or at multiple workplaces. This is the case, for example, in the cleaning services industry and the insurance industry. These persons are “lost” in IDA because they cannot be linked to a workplace since there is no single workplace.

The calculation of employees at workplaces in IDA includes persons with both primary and secondary jobs. In this section, however, those with secondary jobs are omitted in order to avoid a double count when a person with a university degree (Master or PhD) has two places of employment.

In IDA, the identity of a workplace is established over time. This determination of the company’s identity is not made in advance. A company might switch owners, move and so on. The solution to this identity problem is solved in IDA by virtue of its containing data on the employees in such a way that the same labour force is used as a criterion for determining whether the workplace is the same.

Workplaces	
Workplaces in IDA (ex. self-employed)[1]:	212,403
- with employees in November:	174,523
- in the private sector:	126,370
- with a minimum of 5 employees:	57,969
- with a minimum of 5 employees with a university degree:	2,380
- in which the % of employees with a university degree is at least 10 per cent	1,819
Employees	
Employed in RAS[2]:	2,772,868
- of which are employees:[3]	2,549,595
- who are not on a leave of absence from the labour market:[4]	2,530,473
- and who are affiliated with a workplace[5] - which is the same number of employees at workplaces in IDA:	2,367,775
- of which work in the private sector:	1,535,675
- and at workplaces with a minimum of 5 employees:	1,396,396
- and at knowledge-intensive workplaces with a min. of 5 employees with a university degree:	347,959
- and where the % of employees with a university degree is at least 10 per cent	157,789

1 The figures cannot be found again in publications from Statistics Denmark, Statistikbank (Statistics bank) or similar. In Erhvervsbeskæftigelsen (Employment in business and industry) 2000, which includes the self-employed, there are a total of 297,585 workplaces, including 121,199 with only one employee. (See Statistisk Efterretning, General Erhvervsstatistik (Statistical information, General Business and Industry statistics), 2006.6. The one employee is usually self-employed. A portion of workplaces with two employees are a self-employed person with a spouse who also works in the business. The 174,523 IDA workplaces do not include self-employed persons and thus do not include self-employed persons and spousal co-workers either.

2 This figure can be found in Statistisk Efterretning, Arbejdsmarked, Registerbaserede Arbejdsstyrkestatistik (Statistical information, Labour market, Register-based labour-force statistics), 1 January 2001, published 18 April 2002 (p. 9).

3 See note 2.

4 See note 2. On page 12 it is stated that there were 19,122 wage-earners on leave of absence. They are not designated as being at the workplace during the leave – and are therefore not included in the number of employed persons at the workplaces.

5 See the description above of persons who are “lost” in IDA because of a lack of workplace.

The same workplace is involved if one of the following rules is fulfilled from one year to the next:

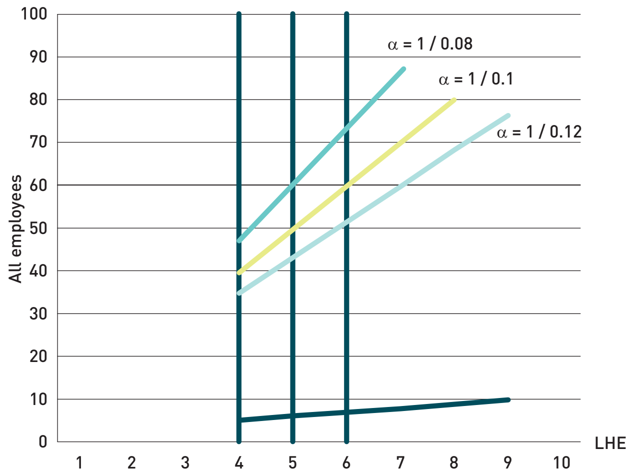
> Same owner and same industry
> Same owner and same workforce
> Same workforce and same address or industry

The determination of the identity of the workplaces makes it possible to follow them from year to year and to illuminate the trend, as was done in the section “The trend in knowledge-intensive companies from 1995 to 2000”. The definitions and limitations described, which were used in IDA and the definition of knowledge-intensive companies, mean that there are fewer persons and workplaces in the data in section 4.2 than in other parts of this report.

The way in which the populations in section 4.2 are set forth on the basis of the Registerbaserede Arbejdsstyrkestatistik (Register-based labour force statistics) and Erhvervsbeskæftigelsen (Employment in business and industry) is shown below.

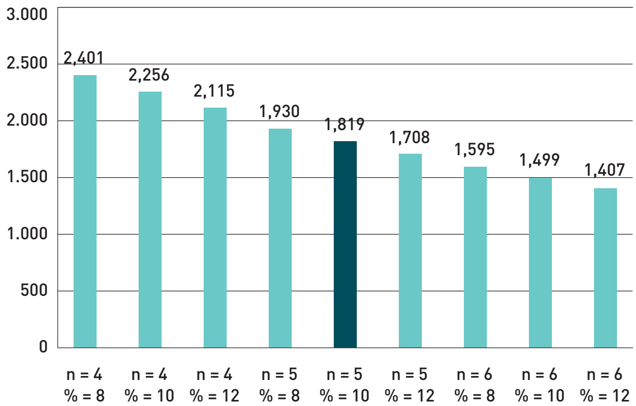
In chapter 4 appear data from the register “Befolkningens Uddannelse og Erhverv” (The population’s education and employment, or “BUE”), which is a linkage between Uddannelsesdata

Figure 1



Source: Statistics Denmark.

Figure 2: Criteria for selection of knowledge-intensive companies



Source: Statistics Denmark.

(Education data) and Registerbaserede Arbejdsstyrkestatistik (Register-based labour force statistics). Thus, the basic data used are the same. The registers' dating differs, so chapter 4 includes data from BUE 2001 and data from IDA 2000. However, they supply data from the same time period, the educational data is from October 2000 and the employment data is from November 2000.

A determination of robustness

The definition of a knowledge-intensive company was not determined on the basis of a previous study. Since the limits can therefore appear arbitrary, we have investigated how robust the definitions are in relation to possible adjustments.

As explained, the definition consists of both a condition regarding the number of employees (a minimum of five employees with a university degree (Master or PhD), and a condition regarding the percentage of such employees (a minimum of 10 per cent of the total number of employees). We investigated how the number of knowledge-intensive companies varied upon changes in either the numeric condition (a minimum of four, five or six employees with a university degree) or the percentage condition (a minimum of 8, 10 or 12 percent) as well as how robust the percentages of employees with a university degree were in relation

Table 2

Min. No. with a university degree	Min. share with a university degree	No. knowledge-intensive workplaces	% change with higher share condition
4	0.08	2,401	6.4
4	0.10	2,256	6.6
4	0.12	2,115	
5	0.08	1,930	6.1
5	0.10	1,819	6.5
5	0.12	1,708	
6	0.08	1,595	6.4
6	0.10	1,499	6.5
6	0.12	1,407	

Table 3

	Min. No. with a university degree	Min. share with a university degree	No. knowledge-intensive workplaces
Num. condition			
	3	-	4,070
	5	-	2,380
	8	-	1,413
	10	-	1,128
Share condition			
	-	0.05	11,126
	-	0.10	9,113
	-	0.15	7,386
	-	0.20	6,461

Table 4

Min. No. with a university degree	Min. share with a university degree	No. knowledge-intensive workplaces	% change with higher share condition
4	0.08	2,401	24.4
5	0.08	1,930	21.0
6	0.08	1,595	
4	0.10	2,256	24.0
5	0.10	1,819	21.3
6	0.10	1,499	
4	0.12	2,115	23.8
5	0.12	1,708	21.4
6	0.12	1,407	

to changes in the conditions (note that the percentage condition is designated as the “share condition” in the tables because the level is represented in decimal rather than percentage form).

At first the outcome range that arises from these combinations is outlined. In figure 1, the vertical lines represent the numeric condition: four, five and six employees with a university degree. The three sloping lines at the top represent the percentage condition: 8, 10 and 12 per cent. The lowest sloping line shows simply the lowest number of employees that there can be with a corresponding number of employees with a university degree. It appears – perhaps not surprisingly – that the outcome range (the area of the figure charted between the limits) becomes larger as the limits become lower. The solid lines represent the limits used.

The actual number of knowledge-intensive companies that results from the nine combinations is calculated afterwards. Figure 2 shows the results of these combinations.

As expected, the number of knowledge-intensive companies becomes fewer as the requirements become tighter. In addition, it is important to point out that the slope between the three columns in each group is the same. Thus, there is a drop of about 6 per cent between the columns, and this can also be seen in the table below.

In other words, the outcome range is not significantly different upon minor changes in the limits.

If the conditions are considered separately, it appears that the more restrictive condition is the numeric condition.

Table 5

Min. No. with a university degree	Min. No. with a university degree	No. knowledge-intensive workplaces	Distrib. of share with a university degree share
Combination of conditions			
4	0.08	2,401	0.19
4	0.10	2,256	0.19
4	0.12	2,115	0.19
5	0.08	1,930	0.19
5	0.10	1,819	0.18
5	0.12	1,708	0.18
6	0.08	1,595	0.19
6	0.10	1,499	0.18
6	0.12	1,407	0.18
Num. condition			
3	-	4,070	0.21
5	-	2,380	0.20
8	-	1,413	0.19
10	-	1,128	0.18
Share condition			
-	0.05	11,126	0.29
-	0.10	9,113	0.29
-	0.15	7,386	0.29
-	0.20	6,461	0.28

Table 6: Media/communications includes the following industries

Industrial industries	
2221	Newspaper printers
2222	Other printers
2223	Bookbinders
2224	Reproduction shops and typesetters
2225	Other companies related to printing
2233	Reproduction of IT media
Service industries	
2211	Publication of books, brochures and the like
2212	Publication of daily newspapers
2213	Publication of weekly, regional, advertising and magazine periodicals
2215	Other publishers
5247	Book and stationery dealers
5272	Repair of electronic households equipment, radio and television repair shops
7440	Advertising and marketing agencies
7481	Photographic companies
9211	Film and video production
9212	Film and video distribution
9213	Film theatres
9220	Radio and television companies
9240	Press agencies
9251	Libraries and archives

Table 7: IT industries include the following industries

The study uses the OECD's definition of IT industries. The definition lists a number of industries that are shown below along with their NACE codes, which define the individual industry. NACE is the system that the EU uses to categorise the industries in the private sector. Under IT wholesale trade, DB 93 is used; it is a Danish subgroup of NACE in which the first four digits correspond to NACE.

IT industry	
NACE	
3001	Manufacture of office equipment
3002	Manufacture of IT machinery and equipment
3130	Manufacturing of insulated wires and cables
3210	Manufacture of circuits and semiconductor components
3220	Manufacture of telecommunications equipment
3230	Manufacture of radios, televisions, loudspeakers, antennas and the like
3320	Manufacture of navigation equipment, measuring and control equipment
3330	Manufacture of equipment for industrial processing plants

IT wholesale trade	
NACE/DB 93	
514320	Wholesale trade in radios and televisions
516410	Wholesale trade in office and IT machinery and IT equipment
516510	Wholesale trade in electrical installation components
516520	Wholesale trade in electronic components

Telecommunications	
NACE	
6420	Telecommunications

IT consultancy	
NACE	
7133	Leasing of IT machinery and equipment and office furniture
7210	Hardware consultancy
7220	Software development and consultancy
7230	Data processing
7240	Database hosting and distribution
7250	Repair and maintenance of office machinery and IT equipment
7260	Other companies related to data processing

Table 8: Pharmaceuticals include the following industries

Industry	
2441	Manufacture of pharmaceutical raw materials
2442	Medical goods plants
331	Manufacture of medical and surgical equipment

The requirement of "a minimum of five employees with a university degree (Master or PhD) at the workplace" thus results in a population of 2,380, while the requirement of "a minimum of 10 per cent of employees with a university degree" results in 9,113 knowledge-intensive companies.

The same picture results if the nine combinations are considered with the same percentage.

An explanation for this is that there are many small workplaces in Denmark. Regardless of the limit set for the minimum number of employees at a workplace, the limit will screen out many small units. In addition, the small workplaces in many industries have no employees with a university degree (Master or PhD) - or perhaps a single one - so the requirement of five such employees screens out many small companies.

On the other hand, the percentage condition screens out some of the very large workplaces from the list of knowledge-intensive companies because the requirement of 10 per cent of employees having a university degree, out of a very large number of employees can be difficult to fulfil. (In the graph, the outcome range is limited on the upper side.) As the tendencies described above show, the total number of knowledge-intensive companies is most sensitive to changes in the number of employees with a university degree and the requirement means screening out many small units. On the other hand, there are very large companies that cannot fulfil the percentage requirement.

Afterwards, we investigated how changes in the limits affect the distribution of the percentage of employees with a university degree - that is, the percentage that the employees with a university degree constitute of the total number of employees. The table below shows the distribution of percentage employees with a university degree both for the nine

>

combinations of conditions and for each of the conditions alone.

It shows that the distribution is generally constant regardless of changes in the limits above the dotted line. The distribution of the four populations of companies that are not limited downwards (the four lowest rows in the table) is somewhat higher.

Altogether, the definitions must therefore be considered robust against minor changes in the limits.

Section 4.3

The focus areas are IT industries, media/communications and pharmaceuticals, and they were examined in relation to the group of the rest of the private sector. These areas are each in their own way representative of the driving forces of the knowledge society and of high growth.

Statistics used

R&D statistics

Data from the Danish Institute for Studies in Research and Research Policy are taken from Erhvervslivets forskningsstatistik (Private sector research statistics), 1999. In certain areas, pharmaceuticals and media/communications are placed under the category "Other" for discretionary reasons.

The study of R&D investment in 1999 was based on data from a questionnaire study based on a random sample from the Danish Institute for Studies in Research and Research Policy and from Statistics Denmark's Firmastatistik (Company statistics) 1999.

The data encompass 3,261 units as a starting point. An analysis of the material showed that there are problems at the unit level (a unit is represented by a CVR No. - company registration number). In certain cases, the unit in the questionnaire study and the same unit in Statistics Denmark's register are not in accordance. After removing units for which there was too a high probability that the units are not in accordance and for which there were other problems with the data, there remained 3,028 units in the study population.

These units are listed with a weighting that reflects the differences in the coverage of industries and the size categories in the random samples and the removals. Thus, the weighting does not capture the removal of units upon the combination of various register data.

Statistics Denmark's new company statistics were used. One implication of this is that there are matches between significantly more units in the study by the Danish Institute for Studies in Research and Research Policy and the Statistics Denmark data, including the inclusion of telecommunications, and that there are significantly more companies in the R&D industry.

On the basis of this material, the 50 companies that invest most heavily in R&D were identified.

Statistics Denmark uses the following sources:

Company statistics

Firmastatistikken (Company statistics) are register-based statistics whose data comprise Turnover statistics, Business and industry employment statistics, General financial accounts statistics for the private sector and the Business and industry statistical register. The statistics include information about turnover, employment and a number of accounting variables, such as value added at the company level, as the statistical units consist of the individual company considered as a legal unit, that is, the individual public limited company, private limited company, sole proprietorship, and so on. The population of Company statistics is those companies whose primary activity is subject to VAT. The statistics are also limited to the private sector. Finally, in the compilation of the statistics, companies with special ownership status, including funds, associations and so on, are excluded, as the statistics are directly primarily towards distinctly commercial and market-oriented activity.

In the charts and the tables, two measures of employment are distinguished. The number employed at the end of November and full-time employees. The number employed at the end of November is a calculation of the total number of employed persons, regardless of whether they are full-time or part-time employees. The figure also includes any personal proprietors of companies.

Full-time employees are a calculated indicator of the total volume of employment. The basis for this calculation is the total of the individual companies' annual payments to ATP (the Danish Labour Market Supplementary Pension); dividing this amount by the annual ATP payments per full-time employee produces an indicator of the volume of employment. This figure does not include any personal proprietors.

The founding of new companies
Statistikken over Tilgang af nye virksomheder (Statistics on the founding of new companies) are register-based statistics whose purpose is to distinguish the actual increase in the number of companies in the individual years. The statistics are based on turnover statistics, Business and industry employment statistics and the Business and industry statistical register. The population of the statistics is the companies that were actually founded, and the statistics contain information about the companies' turnover, exports and number of employees at the end of November. The statistics are limited to the industries in the private sector that are subject to VAT.

Quarterly turnover statistics
Quarterly turnover statistics are intended to illuminate developments in the business cycle and business and industry through quarterly information about turnover and purchases for the individual industries in the private sector. The basis of the statistics consists of VAT-registered companies' monthly, quarterly or semi-annual reporting to the Ministry of Taxation, Central Customs and Tax Administration, in connection with VAT payment, supplemented by background information from the Central Business Register. The survey gives a complete picture of most industry areas in the private sector as well as raw material extracts. For the individual industries, there is information on total turnover and total purchases. Turnover is broken down by domestic turnover, exports and so on. The population consists of the registration units in the register of companies subject to VAT at the Ministry of Taxation.

Import/export
The product nomenclature PRODCOM is linked to the industry nomenclature, NACE. That is, the individual products in PRODCOM are linked to the individual industries. Media goods and pharmaceuticals goods are determined on the basis of the goods (defined according to PRODCOM) that are linked to the individual industries. The combined nomenclature (KN), which is also the product nomenclature, is used in foreign trade statistics. A key has been established between PRODCOM and KN that makes it possible to draw the relevant goods from foreign trade statistics. IT goods are determined in an ongoing, long-term collaboration between OECD, EUROSTAT, national authorities and statistics offices. Foreign trade statistics cover only physical goods, and this means that imports and exports of services are not included.

The IT labour market: Positions and education
Statistics Denmark has undertaken a unique form of development work for the purpose of illuminating labour market statistics. The breakdown of persons according to position is made according to the standard grouping DISCO-88. This grouping is the official Danish edition of the international professional classification ISCO-88. Information about a person's position comes from public sector and private sector wage statistics. The public sector wage statistics are based on wage and personnel statistics registered for public sector employees. Positions in the private sector come from several sources, primarily from private sector wage statistics.

The determination of the educational programmes that can be designated as IT, pharmaceuticals and media/communications educations was made in a rough collaboration among Statistics Denmark, the Ministry of Education and the Ministry of Science, Technology and Innovation. The OECD's definitions were used as a model. IT educational programmes are divided into primary and secondary IT programmes. This classification was used in several publications. For the pharmaceuticals and media/communications areas, the classifications were used for the first time.

The educational programmes indicated in this report are the person's highest completed educational level. The highest educational level comes from the register Befolkningens Uddannelse og Erhverv (The population's education and employment), which is an annual survey of the educational level of the population. A person's highest level of education is defined as the educational programme that, according to the estimated duration, is the longest. The survey is based on a collection of information from educational institutions about a person's educational career on 1 October. This lays the foundation for an overview of all persons' highest completed educational programme.

Companies' use of IT
The study is based on the questionnaire survey from Statistics Denmark "Danske virksomheders brug af IT 2001" (Danish businesses' use of IT 2001).

Companies' responses were gathered in November 2001 in a voluntary, questionnaire-based survey. The questionnaire was filled out by 3,327 companies with at least five employees in the majority of Danish business and industry.

The IT index was developed on the basis of a study carried out in November 2001 as a voluntary, questionnaire-based random sampling among most of the industries in the private sector. The data derive from 763 companies, and this number represents a response rate of 51 per cent. The random sample was undertaken as a random, stratified selection according to the number of full-time employees and the industry. The population consists of companies retrieved from the Erhvervsstatistiske Registersystem (Business and industry statistical register system). Most of the industries in the private sector are represented in the population.

The questionnaire was organised as a question framework that illuminates the use of IT in seven fundamental business processes both *internally* in the company and *externally* in relation to customers, suppliers and collaborative partners, for example. They consist of the following business processes:

> Production
> Marketing
> Management of financial resources
> Training and management of human resources
> Development and design of new products and services
> Protection and management of information
> General or strategic management

The question framework lays the foundation for the organisation of the index. In the index, it is possible to attain a score from 0 to 4, which correspond to four levels of IT use. A low score indicates a limited integration of IT, and a high score indicates a thoroughgoing integration of IT.

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The Danish Government’s Knowledge Strategy - Knowledge in Growth

Background report to “The Danish Government’s Knowledge Strategy - Knowledge in Growth. Policy Statement to the Danish Parliament”

The Background report to the Government’s knowledge strategy consists of two main parts. The first part contains an in depth version of the Government’s knowledge strategy, as presented in the policy statement to the Parliament. The second part includes a wide range of statistical and analytical material, which make up the documentation of the Danish knowledge society and is the foundation for the knowledge strategy.

Among other things, the documentation consists of international research results, which shed light on the theoretical linkage between knowledge and growth. A line of Danish researchers has contributed short presentations of their various reseach, regarding different aspects of the knowledge society. Furthermore, statistics on research, education, innovation and IT- and telecommunications are presented.

Both publications are available at the Ministry of Science, Technology and Innovation’s home page www.vtu.dk.

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The Danish Government's Knowledge Strategy – knowledge in growth

The Danish Government's Knowledge Strategy – knowledge in growth. Policy Statement to the Danish Parliament.

This background report to the Danish Government's knowledge strategy consists of two parts. Part 1 comprises an extended version of the Government's knowledge strategy as presented in the Policy Statement to the Danish Parliament. Part 2 comprises extensive statistical and analytical material documenting the Danish knowledge society and forming the basis for the knowledge strategy.

The documentation includes international research results which shed light on the theoretical relationship between knowledge and growth. A number of Danish researchers have contributed with brief presentations of their research into various aspects of the knowledge society. In addition, statistics on research, education, innovation, IT and telecommunications are presented.

Both publications are available on the Ministry of Science, Technology and Innovation's website: www.vtu.dk.