Section 5

The Danish knowledge system

1. Introduction

This section provides a general outline of the extent of the university research, staff resources and funding, and the extent of the composite research conducted by other public research institutions and private enterprises. In summary the section addresses:

- Public and private investments in research
- University research
- Regional research collaboration in the Øresund region

Facts about Danish research

- In 2001, Denmark spent almost 2.4% of the GNP on R&D (DKK 32.2 bn), which ranks Denmark lower than Finland and Sweden, but above average for the EU.
- Business sector's R&D was in 1999 conducted by the manufacturing industry (2/3) and the service industry (1/3).
- Public sector spending on R&D was in 2000 distributed to the universities (60%), the governmental research institutions (21%) and the remaining to the hospitals and others (19%).
- Natural Sciences received 28% of the total public R&D investment of DKK 9.7bn in 2000.
- In 2001, Denmark was one of the leading nations in terms of the number of scientific publications, both relative to the number of inhabitants and the resources invested in the research system.
- The age composition of the universities' scientific staff points towards a growing annual departure rate due to retirement among the permanent staff over the next few years in particular for the period 2010–2015, and primarily within the humanities, natural science and health sciences.

2. Players in the Danish knowledge system

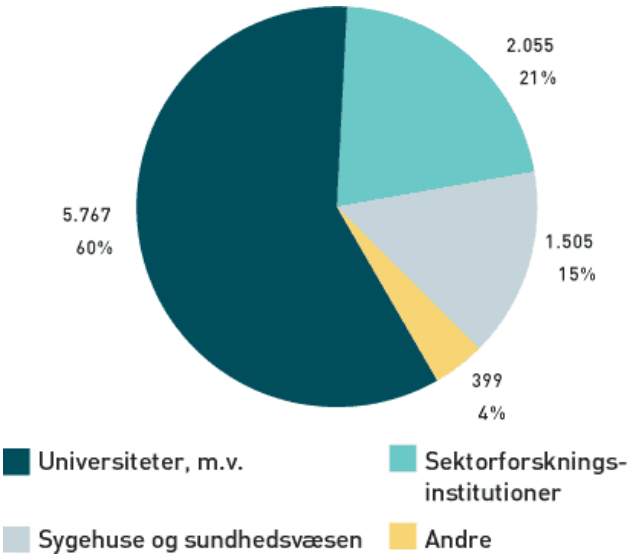
The Danish knowledge system consists of knowledge institutions and private enterprises that produce, attract, disseminate and use research-based knowledge, or other knowledge at a sophisticated level. In this context the knowledge institutions are: universities, governmental research institutions, university hospitals, Approved Technological Service Institutions (ATSI), centres of tertiary education[1] and business academies, plus other institutions such as science parks and innovation environments that help entrepreneurs and others commercialise their research results.

[1] In Danish: Centre for Videregående Uddannelse (CVU)

The Danish knowledge institutions

In 2000, the public research institutions spent almost DKK 10bn on R&D; with almost DKK 6bn spent by the universities, DKK 2bn by the governmental research institutions and DKK 1.5bn by the hospitals and health service. In all, these three areas account for a total of 96% of the public research expenditure, see fig. 5.1. Museums, libraries, centres of tertiary education and the business academies received DKK 0.5 bn for work related to carrying out their functions a regional knowledge centres.

Figure 5.1 Public R&D investments divided onto sectors realising the work, 2000



Source: Public research statistics 2000.

3. Danish universities - profiles and environments

The 12 universities in Denmark vary considerably in size and academic profile, see table 5.1 and fig. 5.2. As already mentioned there are five multi-faculty universities that conduct research and offer bachelor, master (candidatus) and PhD programmes within natural sciences, the humanities, social sciences etc. These five universities are the University of Copenhagen, the University of Aarhus, the University of Aalborg, University of Southern Denmark and Roskilde University.

In addition, there are five single-faculty universities that conduct research and offer educations targeted at a few, clearly defined professions, such as pedagogics, agricultural and veterinary sciences, and technology. These universities are the Royal Veterinary and Agricultural University, the Danish University of Pharmaceutical Sciences, the Danish University of Education, the Technical University of Denmark and the IT-university of Copenhagen[2]. Finally, the two business schools in Aarhus and Copenhagen focus on research and education within languages for special purposes and business economics.

The universities must address three main tasks: Research to the highest international standards, research-based bachelor and master (candidatus) degrees, research training (PhD) and research-based continuing educations. They must also disseminate knowledge to society through collaborative initiatives – a task that is stressed in the new University Act.

[2] Established 1 july 2003.

Table 5.1 University staffing and students in FTE[3]

University	Scientific staff Full-Time	Part-time	Total	Technical and admin. staff	Main figures
AU	1,502	275	1,776	1,528	3,304
DFU	191	11	202	152	353
DTU	1,239	78	1,318	928	2,245
HHA	212	87	299	213	512
HHK	423	200	622	396	1,018
IT-C	39	13	53	50	102
KU	2,069	414	2,483	2,271	4,754
KVL	674	40	715	800	1,515
RUC	444	72	515	286	802
SDU	891	182	1,073	821	1,894
AAU	988	106	1,095	768	1,863
Total	**8,671**	**1,479**	**10,150**	**8,213**	**18,362**

Source: The universities' annual accounts 2001. Exclusive of Denmark's University of Education for which there is no information availabe for 2001.

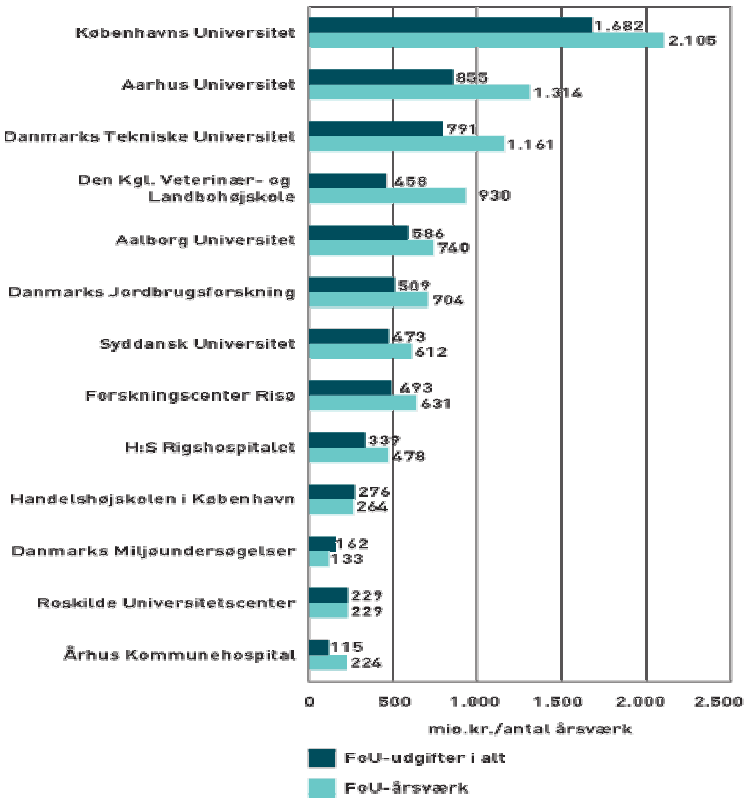


Figure 5.2 The largest public research institutions in Denmark in 2000
Source: Public research statistics 2000.

[3] FTE = Full Time Equivalents

The research conducted in Denmark can be divided between the traditional main areas: the humanities including theology, social sciences, health sciences, natural sciences, agricultural and veterinary sciences, and technology. More than half of the public research is conducted within health sciences and natural sciences; see figure 5.3. The activities within the other areas show a more or less even distribution.

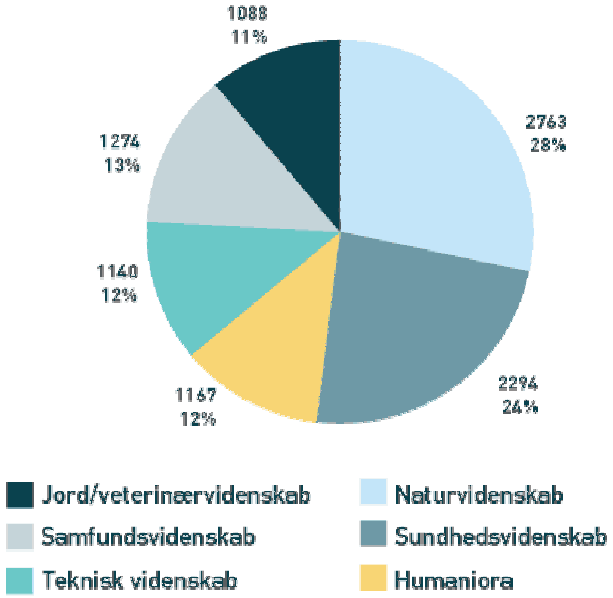


Figure 5.3 Public R&D investments distributed by main areas in MDKK, year 2000 figures

Source: Public research statistics 2000.

The scientific staff at the universities

The permanent scientific staff at the universities (i.e. professors and associate professors) is characterised by an uneven age distribution. The university expansion scheme in the late 1960s and early 1970s, created a large number of new positions as associate professor and researcher that were primarily filled by newly educated master's and young researchers. Following this there was a long period of economic recession, which led to stagnation in the recruitment to university posts. In 1984 new stricter qualification requirements for appointments to posts as assistant professor and associate professor raised the average age of persons recruited to permanent academic posts. This is reflected in the age profile of the permanent academic staff where a marked age bulge has been pushed upwards through the age categories (Ståhle 1999). It is assumed that a similar age distribution applies to the researchers at the hospitals and government research institutions.

Consequently, the number of vacant posts at the universities and also the need to recruit new researchers will increase over the next few years. It should, however, be noted that the age distribution of the total academic staff is fairly even at the universities, see table 5.2. The younger academics are mostly employed in various temporary positions, whereas older staff members are found in permanent lectureships and full professorships. There is, then, a large internal recruitment reserve consisting of research students and younger researchers in post doc posts, fellowships and externally funded posts.

The university sector is characterised by a rather small internal mobility and likewise a very modest external mobility (Ståhle 2003). The university staff and other public sector researchers rarely change sector, which means that most of them leave due to age.

Table 5.2 Age distribution for scientific staff in university jobs that require PhD degrees in percentages, 31 December 1999 (Ståhle 2003).

Age	Hum	Soc sc	Nat	Vet/agri	Health	Tech	Total
-29	**0%**	**1%**	**3%**	**1%**	**2%**	**4%**	**2%**
30-34	**4%**	**10%**	**11%**	**14%**	**8%**	**19%**	**11%**
35-39	**12%**	**15%**	**13%**	**19%**	**13%**	**15%**	**14%**
40-44	**12%**	**14%**	**12%**	**21%**	**12%**	**13%**	**13%**
45-49	**14%**	**14%**	**12%**	**11%**	**11%**	**8%**	**12%**
50-54	**20%**	**19%**	**14%**	**11%**	**15%**	**10%**	**15%**
55-59	**19%**	**16%**	**20%**	**9%**	**20%**	**16%**	**17%**
60-64	**13%**	**9%**	**11%**	**11%**	**13%**	**11%**	**11%**
65-70	**5%**	**3%**	**3%**	**2%**	**6%**	**4%**	**4%**
Total (%)	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Numbers (N)	**1278**	**914**	**1193**	**437**	**733**	**1112**	**5667**

[1] Professors, lecturers, research professors, research lecturers, assistant research lecturers
Source: UNI•C

It can be seen from table 5.3 that the universities will need to recruit an increasing number of researchers in the years to come. The need will be most predominant in the period 2011-2015 when 18 per cent of the researchers are expected to retire, which is an average of 204 researchers per year. The most evident age bulge is found in the humanities, natural sciences and health sciences, whereas the rate of resignation seems stable for the veterinary and agricultural sciences during the two decades. These estimates also suggest that the areas of technology and natural sciences will be the fastest areas to overcome the bulge.

Table 5.3 Estimated resignations of scientific staff in university jobs that require PhD degrees divided onto main areas. Percentages (N)[4]

	Hum	Soc sc	Nat	Agri	Health	Tech	Total	Avg. resign. per y, N
Resig. 2001-2005	10% (128)	7% (64)	8% (95)	7% (31)	10% (73)	8% (89)	8% (453)	91
Resig. 2006-2010	17% (217)	13% (119)	16% (191)	12% (52)	17% (125)	15% (167)	15% (850)	170
Resig. 2011-2015	21% (268)	19% (174)	20% (239)	12% (52)	20% (147)	16% (178)	18% (1020)	204
Resig. 2016-2020	20% (256)	19% (174)	15% (179)	13% (57)	16% (117)	11% (122)	16% (907)	181

[4] Based on Ståhle, table 3.8, average retirement is set at 65 and annual transfer to the private sector at 2% evenly distributed onto age categories. The estimate assumes a stable number of scientific staff.

However, the replacement needs in the 2011-2015 period (i.e. an average of 3,6 per cent per year) does not in itself mean particularly high recruitment needs unless the universities at the same time will see a considerable rise in the mobility of researchers out of the sector.

Table 5.4 Women among the scientific university staff in ordinary and supplementary jobs, 31 December 2000, in percent.

	Hum	Soc sc	Nat	Agri	Health	Tech	*Total*
Professors	12%	9%	4%	7%	8%	3%	**7%**
Lecturers	35%	20%	13%	28%	29%	10%	**22%**
Assistant lecturers	48%	33%	28%	49%	48%	25%	**36%**
Total	**35%**	**20%**	**15%**	**30%**	**26%**	**13%**	**22%**

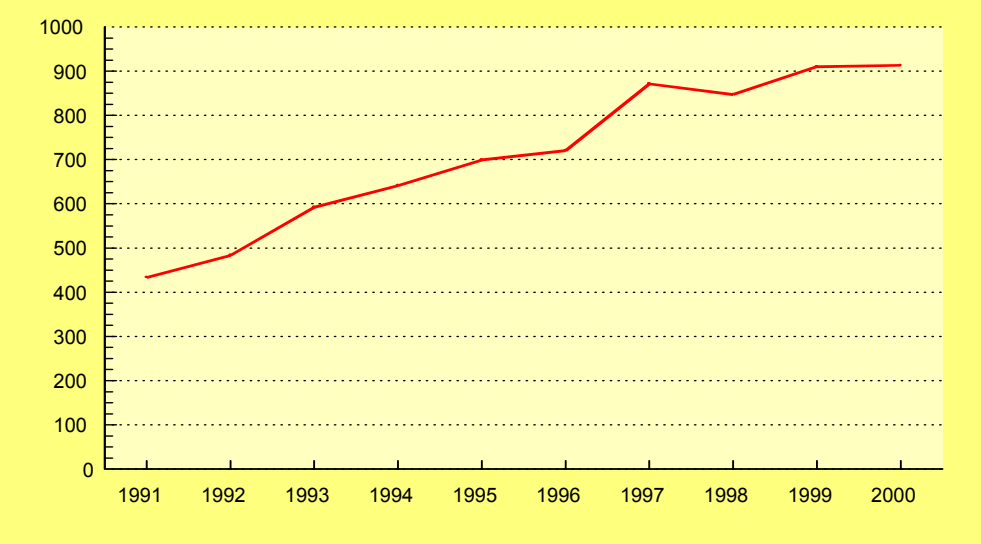
Source: Ståhle, B. (2003), *Forskere søges - ansøgere mangler. Forskerpersonale og forskerrekruttering på danske universiteter 1998-2000 ("Researchers wanted – applicants needed. Danish university research staff and researcher recruitment" – in Danish).* UNI•C.

Table 5.4 shows the percentage of women among the scientific university staff with a clear decrease from assistant lectures to number of professors (only 7% of total). The humanities is the main area with the highest share of female scientific staff with 35%, whereas technology is lowest with only 13% female scientific staff.

Supply of PhDs

The number of PhD degrees conferred increased steadily during the 1990s, but seems to have stagnated after 1997, see fig 5.4.

Figure 5.4 The number of PhD degrees conferred 1991-2000.



To meet the public and private sector's future demand for new researchers the training of a sufficient number of PhDs must be ensured.

Figure 5.5 Estimate of future numbers of PhD degrees per year divided by main areas.[5]
The estimated future number of PhDs. is illustrated by figure 5.5 , which shows a clear difference between the disciplines. The number of degrees awarded in the four main disciplines (the humanities, social sciences, veterinary and agricultural sciences, and natural sciences) is relatively stable, whereas technology and health sciences will award a quite rapidly increasing number of degrees in the period 2005-2010, a number that is expected to stabilise towards the end of the period.
The first trend with a relatively stable number of new PhDs means that the public institutions will have to compete even fiercer with the private sector, if the increased public need for PhDs is to be covered.

The second trend with an increased number of PhD degrees awarded in health sciences and technology is favourable to the public sector. These areas are, however, also expected to experience an increased private sector demand (e.g. the medical and biological industries). A recent analysis within the bio-health area identifies a future insufficiency in the number of PhD degrees awarded (*Bio-sundhedsarbejdskraft og -uddannelser: udbud og efterspørgsel ("Bio-health work force and training: supply and demand" – in Danish)*, 2002, The Ministry of Science, Technology and Innovation).

These PhD estimates assume that the transition ratio from master's to PhD level remains stable and that the completion rates for the PhD educations remain the same. According to a "near-master" survey conducted by the Ministry for Science, Technology and Innovation in 2002, there is an unexploited researcher potential particularly among the students of natural sciences and technology. Generally, in a year of nearly finished masters approximately 2000 students (30% of a year) have considered the option of becoming researchers but remain undecided.[6]

International researcher mobility

According to recurrent surveys PhD app. 10% of a year of PhDs have gone abroad within 18 months of earning their degree. The PhDs in natural sciences head the list with a mobility rate of app. 18%, whereas PhDs in humanities and social sciences have a mobility rate of app. 6%. Of course these unevenly distributed international mobility rates must be seen in the light of the jobs and functions of the individual main disciplines.

According to the surveysPhD, the tendency to go abroad declines with the rising age of the PhD At the same time it appears that PhDs employed abroad return to Denmark after a number of years. The likelihood of a Danish PhD going abroad is highest immediately after he/she has earned the degree, and app. 50% will return to Denmark after five years abroad on average [7]

Table 5.5. Percentage of PhDs employed abroad 18 months after earning a PhD degree

	Hum	Soc sc	Nat	Vet/agri	Health	Tech	Average
Foreign employment	6.8 %	6.4 %	17.8 %	7.9 %	7.0 %	11.5 %	9.7 %

[5] The estimate relies on forecasts for the number of master's degrees conferred, and assumes that the rate of continuation from master to PhD level remains unchanged, and on stable completion rates (the key figures database of the Ministry of Education and *Dansk Forskeruddannelse 2001*, VTU)
[6] Relying on an estimate based on the questionnaire-based survey
[7] (in Danish: *"De ph.d.-uddannede 1997 og 1998", The Research Training Council, 1999 "Status over ph.d.-reformen 1997", The Research Training Council, 1998 og "Naturvidenskabelige ph.d.'er"*, Ministry of Education, 2001 and *"Notat om de universitetsuddannedes udvandringsmønstre"*, Ministry of Science, Technology and Innovation, 2003).

Employment, competition for the positions and researcher mobility

The late 1990s saw a considerable growth in annual student outcome at the universities, when the number of scientific members of the university staff (professors, associate professors, assistant professors) grew by app. 20%.[8] In 1998-2000 on average a little over 70 full professors and about 220 associate professors were appointed annually. This was approximately twice the number of annual appointments of the early 1990s.[9] By the end of 2000, more than a third of the full and associate professors at the Danish universities had been appointed during the second half of the 1990s.[10]

A growing number of these academic posts have been filled without competition. According to a survey published in 1999, for 27% of all vacancies as full, associate and assistant professors in the period 1995-1997 there was only a single applicant per post[11]. The proportion increased to 31% in the period 1998-2000.
The competition is weakest in the field of technology where there is only a single applicant to half of vacancies, whereas the competition is strongest in the field of the humanities and natural sciences with only one applicant for 16% and 22% of the vacancies respectively.[12] Considering the number of *qualified* applicants, the weak competition becomes even more conspicuous since there was only a single qualified applicant for nearly half of all vacancies.[13]

During the period 1998-2000 there were foreign applicants for 40% of the vacancies, an increase by 7-8 %- points compared to the period 1995-1997. However, it should be noted that the general increase conceals a drop in the number of foreign applicants for professorships, whereas the number of foreign applicants for associate and assistant professorships increased.[14] Another point worth noting is that almost a quarter of all vacancies are posted internationally: 49% of the professorships, 25% of associate professorships, and 12% of the assistant professorships.[15]

Since the early 1980s there has been a general tendency for the age of recruitment to increase, and this trend continued during the period 1998-2000. The average age of recruitment in the period 1998-2000 for full professors, associate and assistant professors was 49, 41 and 35 years, respectively.[16], see figure 5.6.

[8] Bertel Ståhle, Forskere søges – ansøgere mangler. Forskerpersonale og forskerrekrutering på danske universiteter 1998 – 2000 (”Researchers wanted – applicants wanted. Danish university research staff and researcher recruitment” – in Danish). Uni-C 2003. p. 20
[9] Ståhle 2003, pp. 34-36

[10] Ståhle. 2003. p. 8
[11] Bertel Ståhle, Alder, køn og rekruttering i dansk universitetsforskning (”Age, gender and recruitment in the Danish university research – in Danish). Uni-C 1999. p. 266
[12] Ståhle, 2003. p. 59
[13] Ståhle, 2003. p. 60
[14] Ståhle, 2003. p. 63-65
[15] Ståhle, 2003. p. 68
[16] Ståhle, 2003. p. 73-74

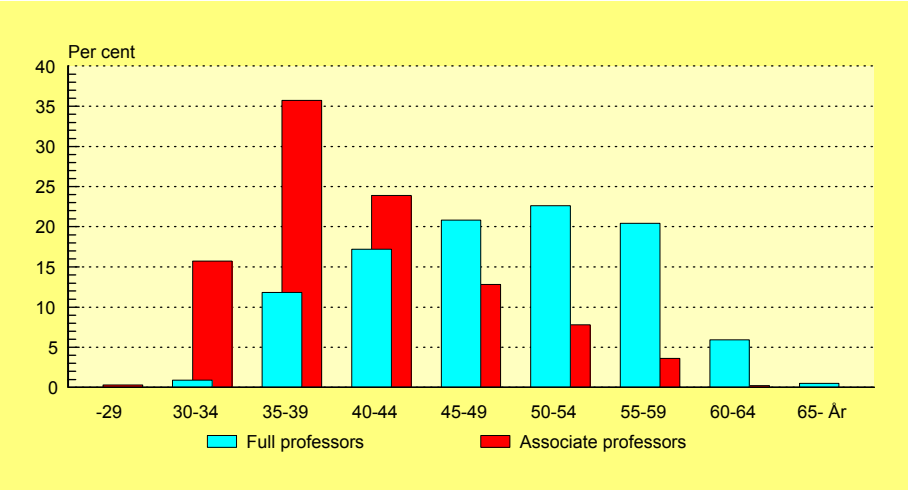


Figure 5.6 Age distribution at the time of recruitment for full professors and associate professors appointed 1998-2000.

Kilde: Ståhle, 2003. *Forskere søges – ansøgere mangler. Forskerpersonale og forskerrekruttering på danske universiteter 1998-2000. ("Researchers wanted – applicants needed. Danish university research staff and researcher recruitment" – in Danish)*)

The mobility exhibited by Danish researchers is very modest. More than a third of the scientific staff employed during the period 1998-2000 was recruited in-house, meaning that they were working at the same institution immediately prior to their employment, se table 5.6. [17] The mobility between the Danish universities is low. As can be seen from table 5.6 it is almost of the same size as the mobility from foreign universities or research institutions to Danish universities.

Table 5.6 Employment in scientific positions for 1998-2000 in % according to the latest place of employment prior to the current employment

	Same university	Other Danish university	Danish governmental research institution	Other public/priv. enterprise	Foreign university or research institution	Others
Professors	63	14	3	12	8	2
Associate prof	72	9	2	5	10	1
Assistant prof.	67	12	2	8	10	1
Total	69	10	2	7	10	1

Source: Ståhle, 2003. p. 79

Research environments

A survey conducted among 258 researchers at 12 university departments[18] suggests that where a good research environment exists, the researchers conduct more research of a higher quality compared to research environments of a poorer quality. The survey describes a good research environment as creative with open academic discussions and mutual understanding. Poorer environments produce less research and fewer publications, and the researchers are under the impression that their working conditions are inferior.

[17] Ståhle, 2003. p. 76-77

[18] Bo Jacobsen, Mikkel Bo Madsen og Claude Vincent: Danske forskningsmiljøer. En undersøgelse af universitetsforskningens aktuelle situation ("Danish research environments. A study of the status quo of university research" – in Danish), København, Hans Reitzels Forlag, 2001.

Generally, university researchers give their academic activities a high priority but they also want an atmosphere of cooperation. Particularly the younger researchers request a more conspicuous management and a better framework for their efforts. These are some of the main conclusions from two surveys conducted by the Danish Institute for Studies in Research and Research Policy.[19]

A surveyaimed at defining how to create dynamic research environments capable of measuring up to the fiercest international competition, focuses on the notion of researcher groups[20]. According to the survey a dynamic research environment is characterised by a basic pluralist view where differences and cross-disciplinary approaches are seen as a resource by the research environment. There is a constant open dialogue on research assignments, theories, and methods as well as on various aspects of publication. These environments are often characterised by a high number of international researchers and extrovert research managers with considerable international academic experience.

According to some surveys special management and staff toolsthat are suitable for public research environments have to be developed [21].
In order to develop and test such suitable management and staff tools for public research institutions, the Ministry for Science, Technology and Innovation is participating in a pilot project involving 12 university departments and two governmental research institutions.

The existence of good research environments is also crucial to young graduates faced with the decision of choosing or rejecting researcher training. The Ministry of Science, Technology and Innovation has carried out a survey of near-graduates' from universities and business schools view on the PhD education. The survey concluded that the students' interest in a PhD education is affected by several factors, e.g.: that the student feels he/she has received adequate information about the education, that he/she is encouraged by a teacher, and that he/she sees the research environment as an inspiring place to work. The survey also points to a close correlation between how the social aspects of the PhD education are regarded and the interest in applying for a PhD scholarship. The pay seems to be of less importance.

[19] 2001/5 "Universitetsforskernes arbejdsvilkår og holdninger til forskningens og forskeres vilkår" ("Working conditions of university researchers and the conditions for research and researchers" – in Danish) the Danish Institute for Studies in Research and Research Policy:
2002/6 "Universitetsforskerne om arbejdsvilkår, forskning og ledelse" ("Universities researchers on working conditions, research and mangement" – in Danish), the Danish Institute for Studies in Research and Research Policy.
[20] 2002/1 "Dynamik og fornyelse på danske universiteter og sektorforskningsinstitutioner – En analyse af hvad der karakteriserer dynamiske og fornyede forskningsmiljøer" ("Dynamics and innovations of Danish universities and governmental research institutions – An analysis of the characteristics of dynamic and innovative research environments" – in Danish) the Danish Institute for Studies in Research and Research Policy.
[21] Peter Dahler-Larsen og Jørgen Gleerup: "Mellem Strategier og Videnstrømme – Vurdering af personalepolitiske instrumenter til omstilling og kvalitetsudvikling på universitets-undervisningsområdet" ("Between strategies and flows of knowledge – Assessment of human ressource policy instruments to convert and develop the quality of university teaching" – in Danish) University of Southern Denmark, 2001

4. Other public research institutions

Governmental research

Denmark has 22 governmental research institutions, organised under 9 ministries covering a wide spectre of activities and academic interests, see table 5.17.

The primary task of the governmental research institutions is to provide research-based on which politicians and public authorities may base their decisions. In addition, the institutions conduct a range of services related to statistics, to supervisory and advisory functions, and to authorities that are important to society. Moreover, they train researchers jointly with the universities. The governmental research institutions account for app. 20% of the total public research conducted.

Table 5.17 Governmental research institutions, staffing and expenses in MDKK, in 2001 figures

Institution	R&D full-time equivalents	R&D expenses
Danish Institute of Agricultural Sciences [1]	704	519
Risø National Laboratory	631	493
National Environmental Research Institute	133	162
Statens Serum Institut (Government body for the prevention and control of infectious diseases and congenital disorders)	200	112
Danish Veterinary Institute [2]	137	107
Geological Survey of Greenland and Denmark (GEUS)	152	101
Danish Institute for Fisheries Research	117	90
The Danish Veterinary and Food Administration	90	84
Danish Building and Urban Research	93	62
National Institute of Occupational Health	106	60
Forsvarets Forskningstjeneste (military intelligence)	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 Infestation Laboratory	19	30
The Survey and Cadastre Agency	33	26
Danish Research Institute of Food Economics	32	23
Danish Transport Research Institute	23	12
Centre for Language Technology	21	12
John F. Kennedy Institute	15	7
Danish Institute for Studies in Research and Research Policy	14	6

Source: Danish Institute for Studies in Research and Research Policy

[1] R&D full-time equivalents for the Danish Institute of Agricultural Sciences are in 2000 figures; R&D expenses for this body are estimates based on 2000 figures.

[2] The figures for Danish Veterinary Institute are based on figures for Danish Veterinary Institute for Virus Research and Danish Veterinary Laboratory that merged in 2002.

In 2001/2002 the Danish Council for Research Policy was asked to review the governmental research in Denmark. The report, *Gennemgang af sektorforskningen ("Review of the governmental research" – in Danish)*, May 2002 gave a number of recommendations concerning models of cooperation between universities and governmental research institutions. Important models are: mutually binding cooperation agreements, consortia, and mergers, with the aim to create better coherence between education, research and innovation.

One of the focus areas was the conditions of contribution from governmental research institutions to the university educations at different levels within specific disciplines where these institutions have special knowledge. Today in particular the health sciences, natural sciences, veterinary and agricultural sciences and technology collaborate to provide tutoring in relation to master thesis and tutoring at PhDlevel Several governmental research institutions also cooperate with the universities to set up research schools. Especially the Royal Veterinary and Agricultural University has extensive cooperation with more than 10 of the governmental research institutions comprising formal cooperation agreements, centres and networks, research schools, adjunct professors and lecturers and more than 200 joint research projects.

In April 2003 the Danish government announced its decision to reduce the number of governmental research institutions from 25 to 17 institutions. New legislation concerning the governmental research institutions will be submitted to the Folketing (Danish parliament) in October 2003.

Hospitals and the health service

Next to universities and governmental research institutions, the hospitals and the health service constitute the third largest player in Danish public research with an annual budget of app. DKK 1.5bn they account for 15% of the total public research expenditure. By far most of this research is conducted under the auspices of the three university hospitals where 18 minor hospitals cooperate at regional level with the faculties of health sciences at the universities of Copenhagen, Aarhus and Southern Denmark.

The university hospitals primarily conduct health science research, focusing on experimental and clinical research within treatment methods, prevention/health promotion, neurology/psychiatry, genetics and biotechnology. Additional research is also conducted by a number of individual clinics and centres, the Danish Cancer Society and to a smaller extent by a number of public hospitals outside the large university cities.

Table 5.8 University hospitals, staffing and expenses in MDKK, in 2001

	R&D full-time equivalents	R&D expenses
Copenhagen University Hospital (10 hospitals) no data for Amagerhospital and the Forskningscenter for Forebyggelse[22])	1059	613
Aarhus University Hospital: (6 hospitals) no data for Psychiatric Hospital for Children and Adolescents in Aarhus	593	293
Odense University Hospital: (2 hospitals) no data for Middelfart hospital	184	119
Total	**1836**	**1025**

Source: Forskning og udviklingsarbejde i sundhedssektoren, Forskningsstatistik 2000 ("R&D in the health sector" – in Danish), Danish Institute for Studies in Research and Research Policy, 2002.

[22] A research centre for preventive measures and health

5. Privately funded research

Research-based businesses

The business sector is a large producer of knowledge, experienced in converting knowledge into new technology and innovation. The Danish business sector is primarily concerned with development work and has steadily increased its R&D expenditure (see fig. 5.7). The Danish business sector invests the equivalent of slightly below 1.7% of GDP in R&D, compared with the so-called leading knowledge economies that invest between 2 and 3%.

In 2001, Danish companies invested about DKK 22bn in R&D. This constitutes approximately two thirds of the total Danish R&D expenses. The businesses primarily focus on development work of commercial relevance (corresponding to 80% off the fulltime equivalent employed in 1999) and less on basic research and applied research.

The knowledge-based industries constitute only a small fraction of the Danish business sector, corresponding to 16% of the total turnover and 18% of the employees, see table 5.9. Knowledge-based industries can be divided in:

- high-technology industries (such as pharmaceutical, computer and telecommunications industries)
- medium high-technology industries (such as chemical, machinery and electronics industries)
- knowledge service industries (such businesses within consultancy, analysis and marketing)

Table 5.9 The Danish business structure

	No. of businesses, 1999	No. of employees, 1999	Employees % with long tert. education	Turnover, % of total 2001	R&D expenses % of the value added of the industry
High-tech. industries	1,440	2.5%	11%	6.1%	18.5%
Medium high-tech. industries	4,800	6.4%	4%	3.4%	6.4%
Knowledge service industries	42,200	9.3%	24%	6.4%	1.4%
Others	187,800	81.8%	3%	84.1%	0.7%
Total private sector	236,100	100%	6%	100%	2.6%

Source: Danmarks Vidensstrategi - Viden i vækst ("The Danish knowledge strategy – growing knowledge" – in Danish), 2003, the Ministry of Science, Technology and innovation 2003

The Danish business sector makes a highly concentrated R&D effort. Almost half (45.5%) of the total R&D investments made by the Danish business sector in 1999 was concentrated on 50 firms, primarily businesses within the computer industry, pharmaceuticals, knowledge service and machinery. Two thirds of all private sector employees with a long tertiary education or a PhD degree are employed in slightly less than 2,000 Danish companies.

In 1999, the manufacturing industry accounted for the largest share of the business sector's R&D investments with a total of DKK 10.3bn, which is the equivalent of 64%, followed by the "knowledge service industries", which accounted for a fourth of the total business R&D investments.

Between 1995 and 2000, the number of new businesses in Denmark increased from app. 14,000 to 19,000 a year. At the same time entrepreneurs within the knowledge service and high-technology industries accounted

for 30% of the new businesses that were founded in 2000 compared to 22% in 1995. Generally, the entrepreneurs within the knowledge service and high-technology industries do a little better than those within other parts of the business sector. Their survival rate is slightly higher, and in particular in the high-technology industries there is a faster than average increase in turnover.

Science parks and innovation environments

The knowledge system also comprises the seven science parks and eight innovation environments in Denmark. The innovation environments contribute to the commercial exploitation of new ideas and research results and support entrepreneurs at a very early stage, when private investors hesitate. Since 1998, the innovation environments have helped establish 420 entrepreneurial enterprises.

The science parks are: Symbion Science Park, the Science Park CAT (Centre for Advanced Technology), the Science Park at Hørsholm/the Innovation Centre, the Science Parks in Southern Denmark, NOVI Science Park in Aalborg, Agro Business Park and Science Park Aarhus. In addition to entrepreneurs these parks also contain other types of innovative enterprises. The science parks are run as self-governing private companies, but funded in various ways by the local, regional and national governments.

Table 5.10 Science parks and innovation environments, staffing and expenses in MDKK in 2001.

Innovation environment	No. of new pre-projects 1998-2001	Promised capital to entrepreneurs 1998-2001 MDKK	Private investments in addition public funding 1998 – mid-2002 MDKK
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 (begun 2001)	11	8	0.6
Total	**420**	**286**	**676.0**

Source: Data provided by the institutes.

Approved Technological Service Institutes

There are 10 approved private technological service institutes (ATSI) in Denmark[23]. They play an important part as producers and disseminators of application-focused technological knowledge, especially to small and medium-size businesses, see table 5.11.

The services offered by the ATSIs comprise testing and certification for advanced technology consultancy, research and development. In 2001, the ATSIs' turnover totalled almost DKK 2.2bn, of which almost DKK 1bn resulted from sales to Danish businesses. The state provides DKK 240m of the funding, which equals 11% of the turnover.

[23] In Danish: Godkendte teknologiske serviceinstitutter (GTS)

Table 5.11 Approved technological service institutes, staffing and expenses in MDKK in 2001 figures

Institute	2001 turnover MDKK	No. of employees 2001	Public funding MDKK 2001
Danish Technological Institute	678	931	95.1
FORCE Technology (incl. Danish Maritime Institute)	574	818	35.7
DHI Water & Environment	301	363	28.9
DELTA Danish Electronics, Light & Acoustics	233	249	24.3
Danish Standard	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
Danish Institute of Fundamental Metrology	17	24	9.3
Total	**2,233**	**2,977**	**242.5**

Source: Data from the ATSIs.

6. Total research investments in Denmark

Total investments in R&D made by the public sector and the business sector amounted to DKK 32.2bn in 2001 an increase by almost DKK 15 bn (85%) since 1991. The public share of the total investments dropped from 41.5% in 1991 to 30.6% in 2001, see figure 5.7.

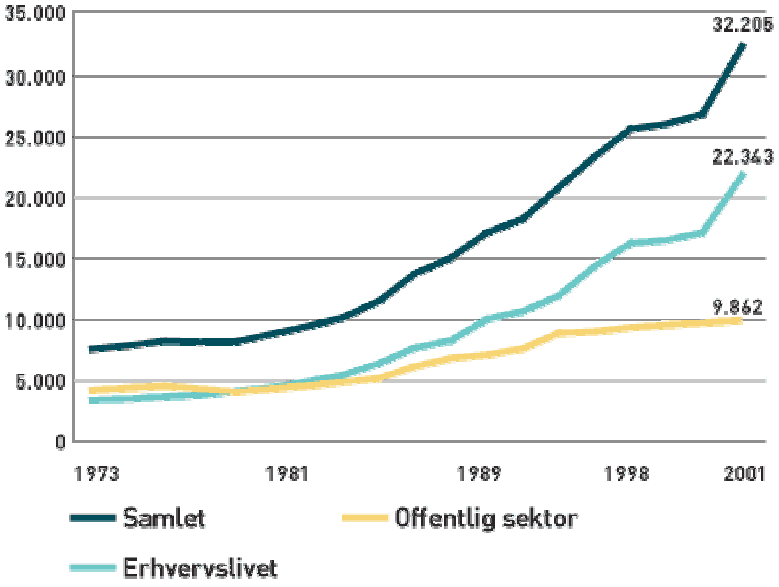


Figure 5.7 Total R&D investments divided onto sectors, 1973-2001, MDKK in 2001 figures

Source: Research statistics 1973-2001

In 2001, Denmark spent about 2.4% of the GDP on R&D, see figure 5.8. In relative terms, Denmark has risen above the EU average during this period, but continues to lie in the wake of the leading R&D nations.

As can be seen the R&D efforts are distributed so that almost a third of the work is conducted in the public sector, which is the equivalent to 0.7% of the GDP for 2001, whereas slightly more than two thirds is

conducted in the business sector, the equivalent of 1.7% of the GDP for 2001. In the countries featuring the heaviest R&D investments, the business sector, however, typically accounts for almost three fourths of the total R&D work.

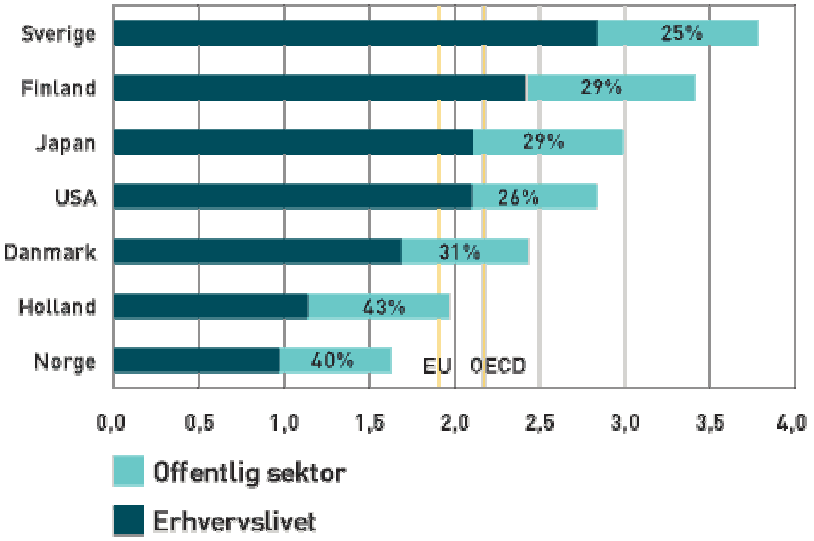


Figure 5.8 R&D as a percentage of GDP divided onto sectors, 2001
Source: OECD: Main Science and Technology Indicators, 2002:2

The Danish business sector is characterised by a predominant share of small and medium size businesses that are not immediately capable of making considerable research investments on their own. Figure 5.9 shows the distribution of the research efforts of the public and the business sectors divided by type of research.

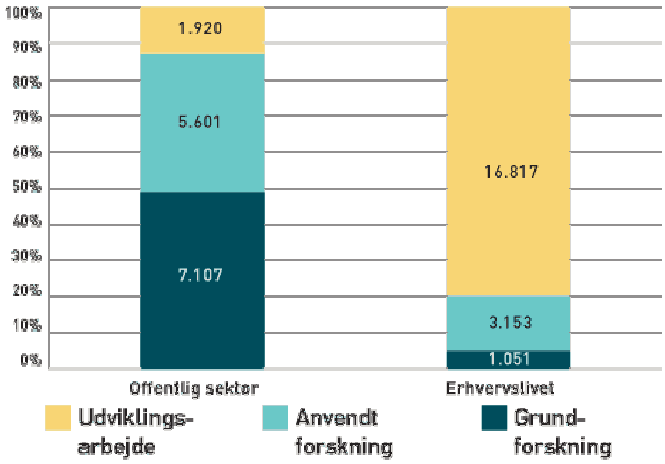


Figure 5.9 R&D distributed onto types of research, based on R&D full-time equivalents,1999
Source: Public research statistics 1999, Erhvervslivets forskningsstatistik (”Business sector research statistics”- in Danish) 1999.

According to the public research budget the total public R&D appropriations for 2002 amounted to DKK 10.6bn . The public R&D appropriation reached a peak for the period 1994-2002.

In 1999, the business sector paid for 90% of its own R&D activities, see figure 5.10. The public sector’s self-funding equalled 81%. In 1999, the business sector funded 3.5% of the public R&D investments, whereas the public sector funded 4% of the business sector’s R&D.

Figure 5.10 Funding of public and private R&D expenses according to sector and main area, MDKK 1999 figures
Source: Public research statistics 1999.

Research staff in the public and private research institutions

The Danish human R&D resources are calculated based on the number of people working full-time or part-time with R&D in the public and the business sector, see table 5.12. The figure is converted to fulltime equivalents which gives a more accurate picture, since a large number of the university employed researchers spend a considerable part of their time teaching, see fig. 5.11.

During the period 1993-2000 the total (public and business sector) number of R&D staff increased by 20% and the number of full-time equivalents increased by 28%, but the rate of increase in the number of people and full-time equivalents has declined in recent years. In 2000, the total number of R&D staff amounted to almost 2% of the total Danish work force. 54% of these were employed in the private sector, whereas 27% were employed at the universities.

Table 5.12 R&D staff divided onto sectors, 2000

	No. of people	% of total work force
Business sector*	28,689	1.00%
Universities etc.	14,244	0.50%
Others, public sector	10,167	0.35%
Total	53,100	1.85%

Source: Public research statistics 2000.
Since there are no business sector R&D figures for 2000, these are 1999 figures.

According to the number of full-time equivalents, Denmark is above average relative to the total work force, but below Sweden and Finland, please see figure 5.12.

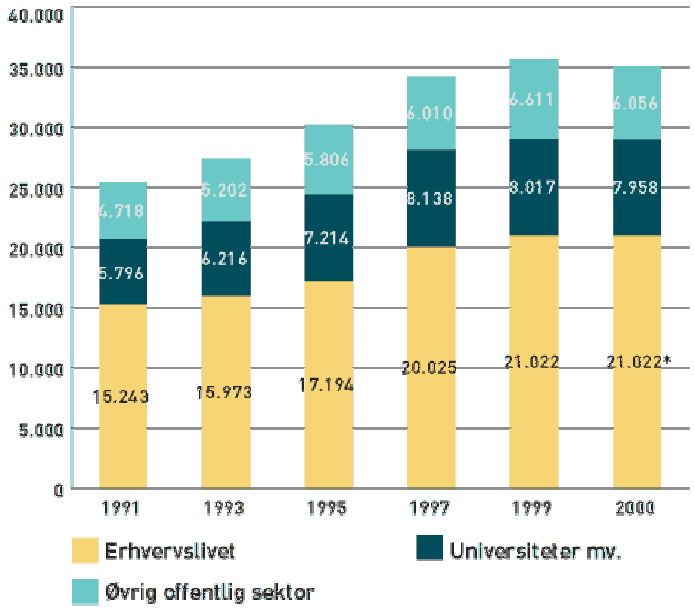
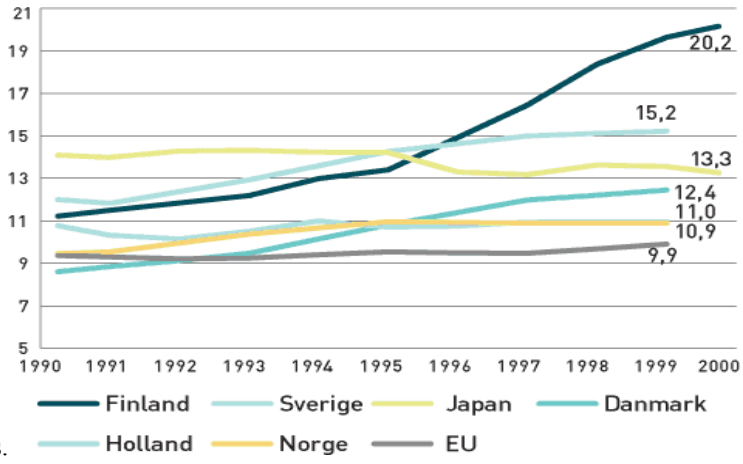


Figure 5.11. R&D full-time equivalents divided onto sectors, 1999-2000.

Source: Public research statistics 2000.
*) Since there are no business sector R&D figures for 2000, these are 1999 figures



figures.

Figure 5.12 R&D staff per 1000 of the work force, 1999-2000.
Source: OECD: Main Science and Technology Indicators, 2002:1

The knowledge systems interact more and more across borders. This also applies to the Danish knowledge system, which to an increasing degree exchanges knowledge with other countries. The direct foreign investments in R&D in Denmark amounted to DKK 1.4bn in 1999, of which almost DKK 1bn was invested in the business sector and DKK 0.4bn in the Danish universities and the other Danish research institutions.

Denmark is number 4 on the list of countries to receive the highest EU R&D funding relative to GDP[24]. Every year Denmark receives about DKK 0.75bn from EU research programmes: 30% of these funds go to the universities, 37% to other research institutions and 27% to the business sector.

Generally, the Danish knowledge institutions and the business sector only cooperate to a limited extent with foreign parties and then in particular with parties that are close, primarily in other EU countries.

Of the businesses cooperating in R&D activities, 30% say that they only cooperate with Danish businesses or knowledge institutions, 25% primarily cooperate with parties within Denmark and the EU, and another 25% also work with partners from other parts of the world.[25]

Export of high-technology products is a good indicator of the level of knowledge contained in the products. High-technology products make up about 20% of the Danish export, which is somewhat lower than comparable nations. For instance the export share of high-tech products is between 30 and 45% for Ireland, The Netherlands, the UK and the USA.

In 2002 about 1700 Masters (graduates) and PhDs emigrated. Within 7-8 years about 2/3 are expected to return giving a net emigration for a longer period of about 600 per year. This figure should be compared with the about 160,000 Danes with a long tertiary education – 30,000 of whom have an education within technology/natural science.

[24] In relation to population Denmark is no. 1. In relation to GDP Denmark is no. 4.

[25] The Danish Institute for Studies in Research and Research Policy: Erhvervslivets forsknings- og udviklingsarbejde ("The business sector's research and development work" – in danish), reseach statistics 1999.

Generally, Denmark has a low number of foreign knowledge workers. On an annual basis, about 400 highly educated people, especially engineers and people with an IT degree, are granted a work permit. To this figure should be added a similar number of immigrants with a long tertiary education. It is not possible to give a more precise illustration of the situation since the immigration and emigration figures are not comparable.

The proportion of international PhD students in Denmark is increasing. The 449 foreign PhD students in Denmark (1999) constitute about 9% of all research students. These students make high-quality contributions to the Danish society from foreign sources. In comparison it is estimated that there are 247 Danish PhD students abroad.

The general situation is that there is an increasing internationalisation of the Danish knowledge system. This is a major benefit to our small knowledge base, although this trend also brings a number of challenges; not least in relation to the question of whether we can attract and keep highly qualified knowledge workers that constitute the foundation of the Danish knowledge environments.

7. Regional and international cooperation

The regional cooperation in relation to Øresund, which was set up in 1997, is briefly described as an example of an ambitious initiative that has been taken to introduce regional cooperation.

Regional research cooperation in the Øresund region

Øresund University is a consortium of twelve universities and university colleges on both sides of Øresund in the Swedish province of Skåne (Scania) and the Danish province of Sjælland (Zealand), a region with 3.2 million inhabitants (2003). Aiming at making the Øresund region a significant science region, the consortium increases quality and efficiency among the participating institutions by opening up all courses, libraries and other facilities to all students, teachers and researchers. The education and research of both countries thus complement each other in making Øresund a scientific and educational stronghold. The twelve vice-chancellors of the participating institutions direct Øresund University. A secretariat manages the day-to-day running of Øresund University and is responsible for co-ordinating all projects in which it participates. The various co-operation efforts within Øresund University take place mainly at faculty and departmental level as projects, networks or formalised agreements about education and research. The co-operation also comprises many other university sectors such as study administration, contacts with society, international issues and information.

The Øresund region has a solid base for development with 140,000 students and more than 10,000 researchers at the twelve member institutions of Øresund University; a large number of high-technology companies, small one-man upstarts as well as major international companies; a number of science parks - some of them amongst the biggest in Europe. In 1990 only 4% of the businesses had a staff of more than 50.

A study from 1999 demonstrates that the private services play a central role to the flow of employees to both the public sector and the knowledge intensive business services (KIBS). But there is no direct cooperation in the Øresund region between universities and innovative businesses, rather a direct coupling via the service sector and in particular KIBS.

A number of consortia have been set up to develop the cooperation between public and private research. *Øresund Science Region* (ØRS) is an alliance between four regional and bi-national network organisations: Medicon Valley Academy, Øresund IT Academy, Øresund Food Network and Øresund Environment. The target is to set up a research community with a competitive edge that can be marketed on a global scale.

A new OECD report on the development in the Øresund region, April 2003, recommends strengthening four aspects of the cooperation: the infrastructure, labour market, knowledge exchange and taxation. The idea is to make it easier to travel around the region, easier to take up jobs on both sides of Øresund, exams and academic qualifications must be acknowledged by both sides, the innovative environments must be strengthened and the two nations should find a common solution to the question of taxation. This means that the authorities must work together more directly.

8. Danish educational research

The below example shows a field of research where Denmark has organised educational research differently from most other countries. In 1999 the Danish University of Education was founded as a merger of three institutions. Supplemented by the other universities, this new university has made it possible to focus on research and educational development across the entire educational sector, where previously there was only a university for the primary and secondary schools. With these targeted efforts new disciplines combine the essence of the educational aspects in order to walk new and transdisciplinary ways.

Danish educational research
Educational research has a unique position in Denmark. In addition to the research conducted at the multi-faculty universities, the mono-faculty university the Danish University of Education also focuses on research in pedagogics. This university was founded on 1 July 2000 as a self-governing institution under the Ministry for Science, Technology and Innovation and is the merger of three institutions: the Royal Danish School of Educational Studies, the Danish National Institute for Educational Research and the Danish School of Advanced Pedagogy.

The Danish University of Education is committed to conducting research and to providing tertiary educational programmes until the level of PhD, as well as continuing education across the full range of educational disciplines. The university strives to enhance the quality of educational research and pedagogical practice in Denmark. The institution also seeks to become an internationally leading university and a dynamic focal point for educational research, training and professional development.

The university's five departments cover: educational psychology, educational sociology, educational anthropology, philosophy of education and curriculum research. A number of these disciplines entail new, cross-disciplinary approaches and lines of research that are to contribute to strengthening and renewing Danish educational research.

According to the general notes of the act on the Danish University of Education the educational research is to rely on close and dynamic interaction between research, education and practice at the educational institutions, pedagogical institutions and other public and private places of work. The institution strives to become an international leader in its field and a dynamic centre of research and education in research, learning and competence development.

Learning Lab Denmark (LLD) is a self-governing institution under the Danish University of Education, which is to conduct a number of experiments on how and when learning and competence development take place and develop. In terms of research, organisation and communication, Learning Lab Denmark aims to be at the forefront in both national and international contexts. LLD aims at closely integrating theory and practice and acts as bridge builder between different sectors. Target groups are the business community and other groups of society.

The foundation of Learning Lab Denmark was preceded by an analysis conducted with the assistance of several ministries. This analysis looked at the perspectives of an increased Danish effort into application focused research on knowledge and competence development. The conclusion was that there is a large virgin

potential to create new knowledge about learning on a *transdisciplinary* and interdisciplinary basis and *across business and educational sectors* – especially in relation to small and medium size enterprises.[26]

[26] The Ministry of Education, Ministry of Economic and Business Affairs, and the Ministry for Research, Technology and Innovation: Learning Lab Denmark. En arbejdsgrupperapport (”Learning Lab Denmark. Report from a working group” – in Danish), Copgenhagen, September 1999, 6.