Innovation, R&D and education in the ICT sector in the Øresund Region

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EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

Interreg IV A
ÖRESUND – KATTEGAT – SKAGERRAK

BrandIT
www.oresund.org/it/projects/brandit

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Print: Wallin & Dalholm Boktryckeri AB
Odlarevägen 10
Box 107
221 00 LUND

1st edition, 1st printing 2010

ISBN: 978-91-974500-1-0

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Preface

This report is prepared as part of a project for BrandIT. The project is funded by Interreg IVA Øresund and the individual participating institutions. The statistical material in this report is based on statistical extracts from Statistics Denmark and Statistics Sweden, as well as from statistics from OECD and Eurostat. In addition, there have been special extracts from the Danish Ministry of Education's database. Statistical information on the ICT research staff, number of ICT students, ICT research and ICT education are collected from the individual institution's administrative offices. The analysis and results of the data have been subject to the authors' interpretation.

We would like to thank the positive and constructive views from the individual institutions that have helped us collect the specific statistics.

This report will be followed by a structural report which includes the development of employment, foreign establishments, new firms and turnover in the ICT sector in the Øresund Region.

There has been an ICT report about cluster development in Europe previously published by Povl A. Hansen and Göran Serin within the BrandIT project: The European ICT clusters – an overview of selected ICT clusters in Europe.

Camilla Christensen, Olivia Bååth and Johanna Jeppsson are the student assistants who collected statistics from the education institutions for this report.

Introduction

In this project report, we will investigate the research and development and education within ICT in the Øresund Region. The access to advanced R&D facilities and a highly educated labour force are the decisive framework conditions for supporting the competitive power of firms in the region, not least to attract new firms, researchers, students and capital to the Øresund Region, thereby continually upgrading the region's international competitive position.

The analysis will be structured as follows: In the first chapter, there will be an analysis of the general trends within ICT, e.g. concerning research fields, user areas and the growth of R&D in different ICT sectors. In the second chapter, business R&D in the Øresund Region will be analyzed. There will be an investigation of the number of R&D staff and expenditures on ICT in the ICT business sector in the region, and the cooperation pattern within ICT innovation will also be analysed. In the third chapter, the public R&D within the ICT sector in the Øresund Region will be investigated. The institutions that conduct ICT research will be registered along with the number of public R&D researchers and PhDs, as well as documenting the research fields within ICT in the Øresund Region. In the last chapter, academic ICT education in the Øresund region will be analysed with regard to both the number of enrolled and graduated students and how the ICT education system in the region is structured in different types of fields and programmes. The analysis in the chapters will be about the Øresund Region level and on specific developments in Zealand and Scania.

To define what constitutes the ICT industry, ICT research and education is not a simple task. We base our definition on the OECD/Eurostat definition (see Appendix V). In addition, there has been a review of each education and research program to ensure that they match the OECD definition. The ability to obtain data and information is strongly dependent on the individual institutions' and universities' own administrative structures and the possibilities of receiving data and information about staff and education structure.

Chapter 1

General trends within ICT R&D

Introduction

In this chapter, there will be a presentation of the general trends within R& D in the ICT sector on both an international level and within Denmark. It will include a mapping of the central research areas and research issues within today's ICT research, the importance of different sub-sectors in ICT R&D and the specific character of research and development processes within the ICT sector.

1. The current international trend within ICT R&D

Today, ICT encompasses all parts of society, and it is impossible to find an area where ICT is not an important part of socioeconomic solutions. ICT is now a precondition for innovation processes covering a wide range of professions and business sectors, including incremental innovations and more radical innovations. There are also a number of areas that attract more attention than others such as in businesses where ICT is a condition for innovative breakthroughs and sectors where it is a condition for a radical innovation development. Therefore, the innovative interaction between these businesses and ICT is crucial for further development. In this project, it is important to register and analyse within which ICT areas and user fields there is a strong international focus and in which sectors we find a strong international growth for ICT R&D. This is important in determining if we can find the same ICT research pattern, or if there is a more specific ICT R&D research pattern in the Øresund Region. If the ICT firms in the Øresund Region shall maintain their international competitiveness in the future, it is important that the research also will be within the areas that are in the cutting edge of ICT research.

The OECD has identified the following six socio-economic fields in which ICT research will play an important role in the near future. These are (Vickery and Wunsch-Vincent, 2009):

- *Health care,* e.g. in the form of health care management, telemedicine, early warning systems, remote surgery and bioinformatics and biomedical images;
- *Environmental challenges,* e.g. ICT for energy-intensive industries, digitalisation and the digital delivery of goods and services, pollution monitoring, etc.;
- *Transport and mobility,* e.g. traffic monitoring, personalised traffic information, software optimisation for freight route planning, sensor and satellite-based navigation and positioning systems, etc.;
- *Independent living and social inclusion,* e.g. accessibility of ICT solutions for impaired users, smart homes technologies and mobile monitoring detection of adverse health, etc.;
- *Emergency and disaster management,* e.g. sensor-based detection systems connected to geo-spatial information systems, interoperability of observation and monitoring systems, etc.;
- *Defence, in the form of,* e.g. command -and-control systems, real-time language systems and surveillance robots, etc.

These identified socio-economic fields are also in line with the strategy of the EU commission's policy for ICT R&D and innovation development in which three R&D projects are given priority: "Innovative ICT solutions for sustainable healthcare", "Innovative ICT solutions for energy efficiency" and an electronic identity management (eID) infrastructure (Commission of European Communities, 2009)

If instead of the socio-economic field, we focus on the ICT subtopic that is on the global agenda in ICT R&D today, the OECD has identified the following eight topics, some of which have been on the agenda for a longer time than others (OECD, 2008):

Physical foundations of computing – This implies achieving better performance and improving the cost and energy efficiency of computing devices, such as the miniaturisation of complementary metal oxide semiconductors (CMOS), as well as optical and quantum computing spintronics.

Computing systems and architecture – The focus here is on improving computing through better integration of single components, i.e. through systems that can effectively scale up and down computing resources in response to sudden changes in requirements.

Converging technologies and scientific disciplines – Increasing interdisciplinary research between ICT, nano-technology and biotechnology opens up new research fields such as imitating natural information processes.

Network infrastructure – Here, we can mention wired and wireless broadband technologies, next generation networks and radio frequency identification (RFID) in sensor-based networks.

Software engineering and data management – Examples in this field are artificial intelligence and natural language processing.

Digital content technologies – The focus here is to facilitate the discovery of patterns in exponentially growing sources and formats of digital information. Examples are automated multimedia content extraction, semantic web technologies and interoperable compression and conversion technologies.

Human technology interface – In this field, research is very much on improved user interaction, ICT accessibility and interaction with all human senses. Virtual realties are also important.

ICT and internet security and safety – Here, the central research fields are quantum cryptography, self-healing computing systems and intrusion detection inspired by immunology.

Of the aforementioned fields, especially physical foundations of computing, computing systems and software engineering have all particularly been on the research agenda for some time, while the merging of ICT with other research disciplines such as nano-technology and biotechnology has lead to ICT pioneering into new research fields.

After qualitatively having identified the focus of the ICT research fields, it is also possible to quantify the research efforts through R&D expenditures and employment.

1.1. R&D expenditures and employment in the ICT sector

The ICT sector is clearly in the lead concerning R&D expenditures and employment compared to other sectors of the economy. A good picture of the strong R&D content of the ICT sector is that this business sector spent more than triple on R&D than the pharmaceutical sector in the OECD area in 2005 (OECD, 2008). The research intensity of the ICT business sector is demonstrated by the fact that the ICT sector represented only about 3% of total employment in the EU-27 and 4.9% of its GDP, while accounting for 26% of its total business expenditures in R&D (BERD) and 32% of its business sector researchers. Measured in percentage of GDP, the EU-27's total investment in ICT R&D amounted to 0.32% of GDP compared to 0.65% in the United States (Turlea et al., 2009).

Figure 1.1 Business ICT R&D expenditures in the United States, EU-15, Japan and Korea from 1996-2005 in billions of current PPP dollars

	1996	2003	2005
United States	55.48206	71.97973	59.58364
EU-15	21.98164	33.49032	34.66576
Japan	18.59504	27.1175	31.63633
Korea	4.734344	10.05248	16.14797

Source: OECD (2008)

The figure above shows that the United States is in the lead concerning ICT research with 72% more ICT than the EU-15, which in turn is slightly ahead of Japan. We can also see that there has been a rise in R&D ICT expenditures in the period from 1996-2005 for both the EU-15 and for competing countries. For the EU-15, the increase amounted to 58%. We can also see that the increase in ICT R&D has been larger in the EU-15 than in the United States – 57.7% compared to 7.4%, but lower than Japan's 70.1%.

If we look at ICT expenditures in the EU-15 divided into business sub-sectors, the following picture emerges:

Figure 1.2 Business ICT R&D expenditures in the EU-15 divided into sub-sectors from 1996-2005 in billions of current PPP[1] dollars by ISIC codes

ICT subsector	1996	2003	2005
30. Office, accounting and computing machinery	2.64113	2.59031	2.60829
32. Radio, television and communication equipment	10.41601	13.60032	13.98239
33. Medical, precision and optical instruments	4.54101	6.94262	6.94620
64.2 Telecommunication	1.78055	3.00854	3.52339
72. Computer and related activities	2.60292	6.77747	7.80031

Source: OECD (2008)

1. Purchasing Power Parity is used for decreasing the impact of price differentials and exchange rate movements over time in international comparisons (Turlea et al., 2009).

Figure 1.2 above shows that R&D in ICT manufacturing (30, 32, and 33) is by far the sector with the highest R&D expenditure on ICT in the EU-15. Two-thirds of the R&D expenditures in the ICT sector are within the ICT industry[2]. The importance of ICT manufacturing R&D is shown by the fact that in 2005 ICT manufacturing R&D accounted for more than a quarter of total manufacturing business R&D expenditures in most OECD countries (Vickery and Wunsch-Vincent, 2009). Telecom is the sector with the lowest expenditure on R&D[3], while computers and related activities, which contains IT service and consultants, had roughly double the expenditure of that of the telecom sector. If we look instead at the increase in R&D expenditures in the period from 1996-2005, we get another picture. Computers and related activities is the strongest growing sector, with a tripling of its R&D expenditures. The telecom sector has also experienced a strong increase in R&D expenditures, nearly doubling its R&D expenditures, while ICT manufacturing has experienced a slower growth with an increase of only 34%. The EU-15 is behind the United States in business R&D expenditure in all sub-sectors except telecom.

Another way of measuring the importance of the R&D of various ICT sub-sectors is to measure the shares of the 100 top R&D spending firms. The result here in 2006 is that electronics comes out with the largest share at 33%, followed by IT equipment at 19%, communication equipment at 17% and semiconductors at 14%, while telecommunications share was only 5% (Vickery and Wunsch-Vincent, 2009). Once again, this points to the strong position of ICT manufacturing in total ICT business research.

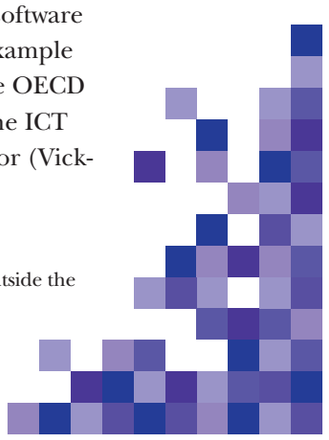
If we look at expenditures instead of focusing on research intensity, i.e. FTE (full-time equivalent) researchers by percentage of employment, there were nearly 100 FTE researchers per 1,000 employed in telecom and multimedia equipment, whereas there were only 15 per 1,000 in telecom services. Generally speaking, the research intensity is much lower in ICT services than in ICT manufacturing (Turlea et al., 2009). Again, this points at the strong dominance of ICT manufacturing in total ICT R&D.

In terms of R&D personnel within ICT, we find the same picture of the United States strongly dominating business ICT research. Of the 943,000 R&D personnel in the ICT sector in the OECD-25 area in 2006, 487,000 came from the United States. The EU-15 accounted for approximately 180,000 and Japan for 147,000. Denmark is among the countries with the largest share of ICT business R&D personnel out of total R&D personnel at 39%, with only Ireland and Finland ahead in Europe at 54% and 51%, respectively (OECD, 2008), compared with 32% for the EU-27 as a whole (Turlea et al., 2009).

A large part of ICT R&D is conducted in non-ICT industries such as the automobile, space, aviation and health care industries. A large part of the R&D expenditures in these fields are on ICT. ICT is often part of non-ICT products, in which ICT is embedded in the product and can therefore seldom be measured or is underestimated. Here, software expenditures play an especially important role in non-ICT industries, where for example in the United States, 30% of all software was developed in non-ICT industries. The OECD estimates that about one-quarter of all ICT expenditures are performed outside the ICT sector. In Denmark, ca. 20% of business R&D was performed outside the ICT sector (Vickery and Wunsch-Vincent, 2009; OECD, 2008).

1. Here, the ICT sector does not include ICT wholesale.

2. It is important to bear in mind that to an increasing extent R&D in the telecom sector is conducted outside the sector by equipment manufacturers instead of telecom providers (OECD, 2009).



1.2 Public funding of R&D research

Eurostat and the OECD have measured the importance of public funding of R&D in the ICT sector based on *government budget appropriations or outlays for R&D* (GBAORD) by socio-economic objectives, which follows the Frascati manual, referred to by the Joint Research Centre (JRC) under The EU Commission (Turlea et al., 2009). In 2005, the ICT GBAORD share of total GBAORD in the EU-27 was approximately 5.4%. The JRC report also reveals that government funding only accounts for a small part of ICT R&D within the EU-27. In 2005, ICT GBAORD only accounted for 12.5% of the gross expenditure on government expenditures on R&D (GERD)[4]. This can be compared with the United States, which had a slightly higher share of GBAORD, amounting to 15.5%. If we look at the total ICT GERD *performed* by the business sector, this sector share becomes even higher, and amounted to 94% of GERD. This is caused by the fact that 6.4% of the R&D performed in the ICT business sector is financed by governments within the EU-27. (Turlea et al., 2009).

From this, we can conclude that the public sector plays a minor role in ICT research, particularly in the performance of ICT R&D.

1.2.1 The organisation of ICT R&D

If we look at the structural organisation of business R&D within the ICT sector, the OECD has identified four characteristics (OECD, 2008). Firstly, there is an increased globalisation of business R&D that is facilitated by the technology itself, as well as by programmes from organisations such as the EU. An important incentive for this globalisation is to exploit available skills. Nevertheless, the majority of R&D is still performed in the home country, which is indicated by the fact that only 12% of business R&D within ICT in the OECD countries was under foreign control. R&D investments are still primarily within the OECD area, although to an increasing extent global innovation networks take place outside the OECD area (Vickery and Wunsch-Vincent, 2009).

A second characteristic or trend identified by the OECD is that ICT research encompasses different sub-sectors of the ICT sector, a process that started in the 1970s.

Thirdly, this collaboration has also become more and more interdisciplinary and stretches outside ICT research. Today, ICT research is integrated with research within nano- and biotechnology.

Finally, the OECD mentions a fourth characteristic or trend, which is R&D partnership around open standards and common technology platforms. A well-known example is the Open Handset Alliance, which is an open source mobile platform with over 30 members.

In spite of these collaborations, however, it is important to bear in mind that firms' expenditures on collaborative research in the ICT sector is low compared to internal research, although OECD statistics show that 34% of ICT firms participate in collaboration compared to 24% of all firms from 2002-2004. According to the fourth Community Innovation Survey, which is referred to by the OECD (2008), 13% of the ICT firms collaborated with universities and public R&D institutions compared to 8.5% for all firms in France, Spain, Germany and the United Kingdom from 2002-2004. Still, this result stands in contradiction to a Danish Study, which shows that Danish ICT firms have fewer joint innovation activities with other firms than firms in general (The Danish Ministry of Science, Technol-

4. GERD is the sum of research and development performed by the business and government sectors. In the JTC report, the non-profit sector is also included in the business sector, while the government sector also includes the higher education sector. Government expenditures on R&D consist both of funds destined for ICT performed by universities and state institutions and funds destined for business (Turlea, 2009).

ogy and Innovation, 2003)[5]. Investigations by the Danish Ministry of Science and Technology in accordance with the OECD show that research conducted by firms account for the main part of R&D within the ICT sector. This in turn is underpinned by another Danish study that demonstrated that university research is more oriented towards basic research than development, while the same investigation also showed that only 0.2% of firms' continuous R&D expenses were on the purchase of public R&D (Gravesen and Mark, 2002).

The OECD (2008) also points out that ICT firms rely on their own internal R&D resources in strategic areas. This dependence does not imply that the ICT sector is independent of university and university research. On the contrary, a strong focus on its own R&D requires a highly educated labour force. This demands that university research be at the forefront for supplying the ICT sector with the necessary labour force, thereby enabling the firms to pursue cutting edge technology and innovation development. As a result, the most important interaction between universities and firms within the ICT sector is in the field of education (Hansen and Serin, 2006). One manifestation of this interaction is that to an increasing degree PhDs become involved in company research (Vickery and Wunsch-Vincent, 2009).

1.2.2 R&D in the Danish ICT sector

In 2007, the expenditures of business R&D in Danish ICT firms[6] amounted to DKK 9.9 billion, whereas the expenditures for public R&D amounted to DKK 639 million. This implies that ICT R&D accounted for 23% of total R&D in Denmark. ICT business R&D accounted for 31% of total business R&D in 2007, and public ICT R&D in accounted for 5% of total public R&D (Statistics Denmark, 2009).

Invest in Denmark has identified four areas in which Denmark has a strong position (Danish Agency for Science, Technology and Innovation, 2008). These are:

- Wireless and mobile technologies
- Pervasive computing
- Software development
- Acoustic and electro-acoustic technologies.

Among other things, the strong position within *wireless* includes radio frequency technology, embedded software, chip-set-reference design, mobile business solutions and production technology. According to Invest in Denmark, this position is based on Danish firms' competencies within all forms of development in communications platforms from wireless B-PAN to wireless MAN, including satellite technology. The existence of advanced users and competencies within design and user interfaces is also important for the strong position.

Pervasive computing is ICT is accessible whenever and wherever. The focus here is to develop and adapt products to different user contexts and user interfaces, which do not require specific user ICT competencies.

Denmark also has a strong position in the development of integrated complex *software systems*, e.g. with language programs such as Turbo Pascal and Visual Prolog. Important success factors have been user-focused design, in which inter-disciplinary design groups and users have secured functional software solutions.

5. Although a Danish investigation revealed that 24% of ICT firms were collaborating with universities and 9% with other R&D institutions (The Danish Institute for Studies in Research and Research Policy, 2004).

6. Business ICT R&D not only includes R&D within the ICT sector, but also ICT R&D within non-ICT industries. (Danish Statistics, 2009)

The last strong ICT field identified by Invest in Denmark is *acoustic and electro-acoustic* technologies. Here, Denmark has many world leading firms such as Brüel and Kjær, Bang Olufsen, GN Resound, Oticon, Danovox, etc., all of which have developed advanced concepts for acoustic communication. In this field, there is a strong emphasis on research concerning the human perception of speech and general research in hearing and development capabilities within loudspeakers and hearing aids.

To these strong positions, Invest in Denmark has added an upcoming field in the form of the computer game industry (Danish Agency for Science, Technology and Innovation, 2008).

If we look specifically at public ICT R&D in Denmark, an investigation carried out by the Danish Technological Institute (2008) has identified some research fields in which Danish public R&D holds strong positions, and it is here that we can find some similarities with Invest in Denmark's general analysis of Denmark's ICT sectors positions of strength. This investigation also stresses the user-oriented character of public ICT research with a focus on business solutions where there is also an opening to other disciplines. The disciplines mentioned are biology, geology and economics because the user fields include the oil, energy, agriculture and food sectors. Health care and logistics are other fields where Danish public ICT research stands strong because of a close user interface. More specifically, communication technology and optical communications are mentioned, in which DTU-Photonics is among the 3-5 leading research institutions in the world. According to the report, other specific research fields where Denmark stands strong are embedded software and database (Aalborg University) and IT security, encryption, pervasive computing, massive data systems and object oriented programming (Aarhus University and IT University). The report also stresses the broadness of the position of strength of Danish public ICT research.

Another way of measuring the position of strength in Danish public ICT R&D is by using a bibliometric analysis to measure the number of published peer reviewed articles and citations (Schneider et al., 2008, Danish Agency for Science Technology and Innovation, 2008). This analysis shows that Danish public ICT R&D has its strongest impact in the following groups:

1 - General topics, engineering mathematics and materials science;
2 - Components, electronic devices and materials;
3 - Optical materials and applications, electro-optics and optoelectronics;
4 - Power systems and applications; and
5 - Control technology.

The Danish government has also put a focus on green IT through an action plan, which among other things, includes support for research projects with a focus on energy saving (The Danish Government, 2009).

Chapter 2

R&D and innovation in ICT firms in the Øresund Region

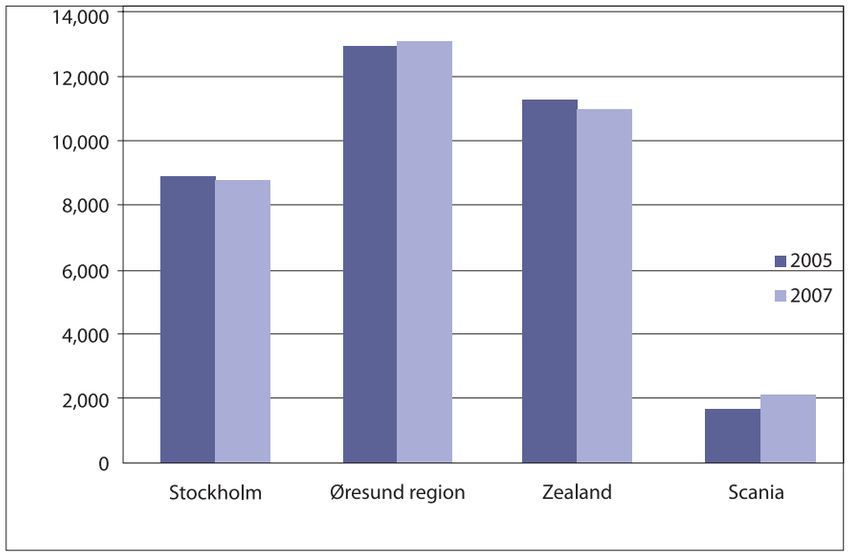
In this chapter, there will be an overview of the research and development resources within the private ICT sector in the Øresund Region. It is not possible to obtain data of the same quality and on the same level in the Danish and Swedish part of the region. The Danish innovation and R&D statistics are significantly more detailed and comprehensive than the Swedish. Therefore, there will only be information in some fields on the Zealand ICT sector. Nonetheless, we have chosen to include these fields because the Zealand side of the region is by far the larger of the two.

2.1 Development of research activities in the ICT industry in the Øresund Region and Stockholm

The number of R&D employees in ICT companies tells us a great deal about research and development activities in a specific industry. This is especially applicable for ICT companies, where R&D and innovation are important for their competitive power. The firms' access to R&D skills is essential for maintaining a high level of innovation, but there are also other ways to bring knowledge into firms other than through their own R&D efforts. For example, this can be done by collaboration with other firms or by buying competencies in form of consulting. Unfortunately, it is only possible to obtain information about innovation structure from the Danish part of the Øresund Region. We will, however, use these statistics because we assume that they are also representative for ICT firms in the Scanian part of the region. Moreover, Zealand constitutes the most important part of the ICT sector in the Øresund Region.

It is also important to point out that the database for the collection of R&D statistics is different in Denmark and Sweden. In Denmark, it includes firms with as little as six employees within ICT manufacturing, while including firms with as little as two employees concerning IT services. The Swedish R&D statistics only include companies with more than 10 employees, and it is not possible to obtain the total investments in R&D on a regional level in Sweden. You can only get your own expenditures on R&D, which means that bought R&D is excluded. Because of this, it is necessary to be extremely cautious when carry out a comparison between different countries. In any case, the database should give a fairly good picture of the trends in R & D employment and investments in the Øresund Region.

Figure 2.1 The number of R&D staff in ICT companies in the Øresund Region and Stockholm from 2005 to 2007



* For Sweden, only firms with a staff of 10 and more are included.
Source: Statistic Denmark and Statistics Sweden, special extracts

As the figure shows, there has been a decline in the number of R&D staff in both Stockholm and Zealand, although particularly in Zealand. Interestingly, there has been a rise in Scania in R&D staff for the same period. This is somewhat surprising, because this trend clearly differs from the trend in both Stockholm and Zealand.

Figure 2.2 The number of R&D staff in ICT companies in the Øresund Region and Stockholm from 2005 to 2008

	2004	2005	2007	2008
Stockholm*	NA	8,892	8,782	NA
Øresund	NA	12,934	13,033	NA
Zealand	8,845	11,271	10,938	9,214
Scania*	NA	1,663	2,095	NA

*figures for Sweden are for firms with a staff of 10 or more. This gives an underrepresentation of the Swedish portion.
Source: Statistics Denmark and Statistics Sweden

In Zealand, there is data over a longer period than has been possible to obtain for Scania and Stockholm. The Zealand data can therefore better predict the development direction. Here, it is also possible to obtain information for different parts of the ICT industry.

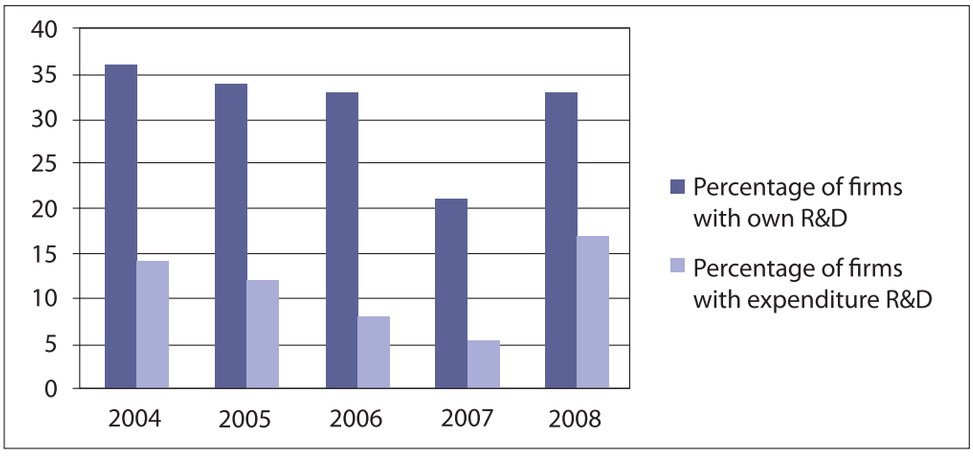
Figure 2.3 The development of R&D staff in the ICT sector in Zealand from 2004 - 2007

	2004	2007	2008
ICT production	1,488	997	1,149
ICT wholesale	1,159	421	524
Telecommunications	1,594	208	363
ICT service and consultancy	4,604	9,311	7,179
Total	8,845	10,938	9,214

Source: Statistic Denmark, special extraction

As the figure shows, there is a decline until 2007 in all parts of the ICT sector except for service and consultancy, which has experienced very strong growth.[7] Noteworthy is the sharp decline in the telecommunications sector. In 2008, there is a strong increase in all parts of the ICT sector except in ICT service and consultancy. The decline until 2007 could indicate the purchase of services from outside to an increasing extent. This could also be the reason for the decline in firms' own R&D personnel. It is possible through innovation statistics to examine whether this is the case.

Figure 2.4 Percentage of ICT firms with R&D activities in Zealand from 2004 – 2008



Source: Statistics Denmark, special extracts

As the figure reveals, there is a decrease not only in the number of firms with their own R&D, but also in the number of companies that purchase R & D from other firms, especially in 2007. There is also a decrease in the number of firms engaged in innovation activities in the ICT sector, although this trend changed significantly in 2008. The data shows that 2007 was a very special year, although there has been a tendency to decrease from 2004. It is also clear that this trend changed in 2008. It should be noted that it has not been possible to obtain data from the Swedish part of the region for 2008 because the Swedish authorities do not collect R&D data annually.

7. There has been a change in the composition of the industry that may explain part of the increase.

Although the innovation process in ICT companies primarily takes place within the company, it is also interesting to see who ICT companies have R&D relationships with and from whom they buy their R&D services. ICT firms are largely responsible for their own development and innovation, but they also cooperate with other R&D suppliers. It is primarily other firms that supply R&D to ICT firms, with these firms delivering 79% of the R&D purchased.

If we look at the Danish suppliers of R&D to ICT companies in Zealand, they can be categorised as in the figure below. The figure should be read as follows: Column 1 shows different types of suppliers of R&D. The percentage shown in the figure in Column 1 is the percentage of their R&D supply which goes to the sector along the dotted line. Column 2 is where the suppliers of R&D services have their main area of cooperation, which is expressed in the percentage of their total R&D collaboration in Danish kroner (crowns). Other firms have for example 78% their collaboration with the sector "development of standard software". Column 2 shows the customer perspective, i.e. the percentage of total bought R&D which comes from this supplier, in this case other firms, where for example the development of standard software gets 84.4% of their bought R&D from other firms.

Figure 2.5 Sectors where R&D suppliers have their most important partners in Zealand ICT companies in 2008

1. Suppliers area and most dominant R&D partners	**2. Largest R&D customers**
Others firms 78%	Development of standard software (84.4%)
Other important R&D partners in the area of " Others Firms"	Manufacturing of radio, television, speakers, antennas, etc. Wholesale of computers, software and telecommunications equipment, etc. The delivery of software consultancy and software
2. Firms in their own group 14.9 %	**Manufacture of other measuring and control equipment (64.9 %)**
Others important R&D partners in the area of " Firms in their own group"	Database hosts and facilitators Manufacture of navigational, measuring and control apparatus. Development of standard software
3. Universities 90.6 %	**Telecommunications (70.6 %)**
Other important R&D partners in the area of universities	Manufacture of other measuring and control equipment. Wholesale with computers, IT and telecommunications equipment. Data processing

4.*GTS - Advanced Technology Group 100 %	**Manufacture of radio, television, speakers, antennas, etc. (90%)**
5. Other public institutions 100%	**Manufacture of other measuring and control equipment 0.1 %**

Source: Statistics Denmark, special extracts

* Network of independent Danish research and technology organisations.

Column 1 in the figure shows that universities have 90% of their R&D cooperation with the telecommunications sector. In column 2, we can see that telecommunications has some other partners, so their R&D purchases from universities only represent 70.6 % of their total R&D purchases. It must be pointed out here that our review in Chapter 3 provides a more nuanced picture of the cooperative relationship between university research and the ICT industry.

It is worth noting that other firms totally dominate the supply of R&D within ICT, but firms in their own group are also important for R&D transfer and for cooperation within R&D. On the other hand, public institutions and universities play a minor role as an R&D supplier and cooperation partner. They only represent 1.2% of total "bought" R&D by ICT firms, so information transfer between firms in the ICT sector is very important. R&D cooperation between firms totally dominates the cooperation structure within the ICT sector.

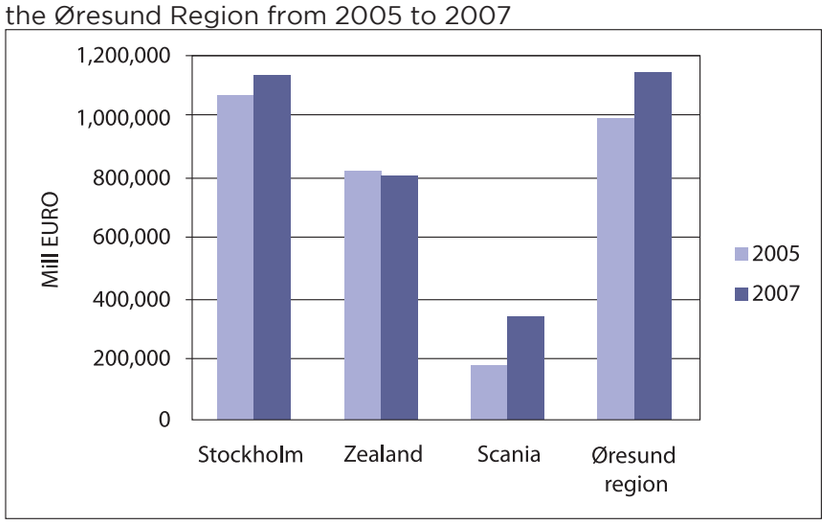
Figure 2.6 R&D divided into different suppliers in the ICT sector by percentage in Zealand for 2008

Other firms	79.7%
Firms in their own group	18.9%
Universities and public institutions	1.2%
GTS institutions	0.02%
Others	0,2%

Sources: Statistics Denmark, special extracts

This study is based on the fact that only 17% of the firms in the ICT sector bought their R&D from outside the firm in 2008. It is also noteworthy that the consultancy business is the most important client group within R&D. The large share of other companies in the investigation may indicate that there is a good cooperation between companies in the innovation process.

Figure 2.7 Expenditures on R&D[8] in ICT firms in Stockholm, Zealand, Scania and the Øresund Region from 2005 to 2007



Source: Statistics Denmark and Statistics Sweden, special extracts

The figure shows that there has been a change from 2005 to 2007 in R&D expenditures in ICT firms. Both Stockholm, but particularly Scania have had an increase in expenditures on their own R&D investments. In contrast, Zealand has had a decrease in expenditures on R&D. Because of the strong increase in their own R&D investments in Scania, the Øresund Region had an increase in R&D investments between 2005 and 2007. In the entire Øresund Region, there was an R&D investment of EUR 1,140,110 in 2007, but Stockholm came very close with an investment of EUR 1,133,730.

There are more than 13,000 people employed in R&D departments in the Øresund region's ICT companies, and the companies used EUR 1,140,110 for development in 2007. It is first and foremost consultancy firms which have the largest share of R&D resources. After a decline in R&D resources, there was an increase again in 2008, especially in the Scanian part of the region.

8. It was not possible to obtain the total R&D expenditures on a regional level for Stockholm and Scania. Therefore, the R&D for these regions only includes their own R&D expenditures and not R&D which was purchased.

Chapter 3

Research & development in the public sector

3.1. Research and development within ICT in the public sector in the Øresund Region

Research in ICT public institutions as well as in related areas play an important role in the education system for the Øresund Region, which will be addressed in a following chapter. The results of our study of innovation and R&D development in ICT companies shows that universities and public research institutions do not play a major role for innovation and development in ICT companies, although there are new businesses that grow as a result of spin-offs from university research. At the same time, providing a high level of research is important for the quality of education, which in turn will be important for ICT firms that rely on a highly educated staff to perform innovative development in the firm.

Our direct contact with research institutions in universities and higher education also confirms that the figures in government innovation studies shown in Chapter 2 underestimate the relationship between research and ICT firms. This theme will be addressed in a subsequent report.

Figure 3.1 The amount of ICT R&D staff in public institutions in the Øresund Region in 2009

R&D staff	2009
R&D staff Zealand	489
R&D staff Scania	165
R&D staff Øresund Region	654

Source; Secretariats of the departments

In 2009, there were 654 persons engaged in public R&D in the Øresund Region. In the following sections, we will investigate how this R&D staff is distributed between various R&D institutions based on statistical material from the institutions, and also present the main areas of research.

3.1.1 The public ICT research institutions on Zealand

In 2009 in Zealand, there was ICT Research conducted at seven ICT institutions, and 489 persons were engaged in ICT research. The ICT researchers are distributed at the following institutions. The Technological University of Denmark strongly dominates ICT research, with more than half the ICT research staff in Zealand.

Figure 3.2 R&D Institution and R&D staff in Zealand from 2004 - 2009

VIP staff at public ICT institutions in Zealand	2004	2005	2006	2007	2008	2009
IT University Copenhagen	48	46	45	47	54	62
Copenhagen University	33*	29*	31*	31*	31*	47
Aalborg University Ballerup	0	3	9	12	13	14
Roskilde University	11	12	12	13	13	13
Technological University of Denmark	218	NA	244	215	230	280
Copenhagen Business School	66	66	65	75	73	73
Total	376	NA	408	393	414	489

Source: Reports from R&D institutions

* Only for Department of Computer Science

Each department's R&D staff and research will be discussed in the following on a general level.

1. Roskilde University

	2004	2005	2006	2007	2008	2009
R&D Staff	11	12	12	13	13	13

Source: Secretariat of the department

Research areas: Research is undertaken by two groups. The main research topics in the group of *Programming, Logic and Intelligent Systems* are: knowledge-based systems and intelligent interaction with systems, logic and knowledge representation, and in the group *User-Driven IT innovation:* programming languages and tools, evaluation and effects-driven IT development, computer-mediated communication and coordination in complex organisational contexts and Software Process Improvement (SPI).

2. Aalborg University/Ballerup Campus

	2004	2005	2006	2007	2008	2009
R&D Staff	0	3	9	12	13	14

Source: Secretariat of the department

Research areas: Computer and Control Technology, Information Technology, Numerical Analysis and Theoretical Computer topics, Computer applications, general topics, Engineering, Mathematics and Materials Science, Media Sociology, Computer Games, Musical Interfaces, Engagement in Interactive Media and Games, Interactive Storytelling, Computer Vision.

3. University of Copenhagen

At the University of Copenhagen, there is one department and 2 centres that have ICT research and development.

A: Department of Computer Science

	2004	2005	2006	2007	2008	2009
R&D staff	33	29	31	31	31	24

Source: Secretariat of the department

Research areas: Research is performed within three different research groups and a number of centres and laboratories: 1. Human Centred Computing (HCC) designs and implements systems; 2.The Algorithms and Programming Languages Group (APL) develops discrete optimisation algorithms inspired by practical problems in bioinformatics, electronic chip design and logistics; 3.The Image Group performs research in image processing and computer simulation of plausible motion, e.g. for use in medical imaging and visualisation, robotics, computer games and movies.

B: e-Science Centre

	2004	2005	2006	2007	2008	2009
R&D staff	NA	NA	NA	NA	NA	13

Source: Secretariat of the department

Research areas: Researchers in the centre are actively involved in projects in medical image analyses, high performance numerical algorithms for nano-scale modelling, data acquisition from hostile environments, molecular docking, large-scale chemical screening and numerous projects on middleware for high performance computing and grid.

C: The Bioinformatics Centre

	2004	2005	2006	2007	2008	2009
R&D staff	NA	NA	NA	NA	NA	10

Source: Secretariat of the department

Research areas: The Centre has subgroups working in non-coding RNA, gene regulation and protein structure prediction. The research specialises in probabilistic models and machine learning. They collaborate with many experimental groups in the department, at BRIC and at other institutions around the world: 1. Structural bioinformatics group; 2. Protein structure ensembles from mathematical models – with application to Parkinson's alpha-synuclein; 3. Comparative Genomics; 4. microRNAs; 5. Promoter analyses.

4. IT University of Copenhagen

	2004	2005	2006	2007	2008	2009
R&D staff	48	46	45	47	54	62

Source: Secretariat of the department

Research areas: The IT University of Copenhagen has strong competencies in health informatics and welfare technology. The IT University also has expertise in "Green IT", with a special area of research in gauze tracking. Other research areas are the use of computer games in new and surprising relations, cloud computing, ubiquitous/pervasive computing and process-oriented IT.
Private R&D cooperation: In research projects, the IT University of Copenhagen has private research cooperations with 41 firms in 2010.

5. Technological University of Denmark

At the Danish Technological University, there are four departments, which conduct ICT research.

A: DTU Photonics

	2004	2005	2006	2007	2008	2009
R&D staff	58	NA	77	52	85	104

Source: Secretariat of the department

Research areas: General topics, Engineering, Mathematics and Materials Science, Components, Electron Devices and Materials, Optical Materials and Applications, Electro-optics and Optoelectronics, Electromagnetic Fields, Communications.
Private R&D cooperation: In research projects, the Photonic Department has private research cooperation with 28 firms in 2010.

B: DTU Informatics

	2004	2005	2006	2007	2008	2009
R&D staff	75	NA	80	94	79	91

Source: Secretariat of the department

Research areas: Mathematical Statistics, Image Analysis & Computer Graphics, Cognitive Systems, Scientific Computing, Language-based Technology, Software Engineering, Algorithms and Logic (Algolog), Embedded Systems Engineering.
R&D cooperation: The department is a partner in nine international projects.

C: DTU Electrical Engineering

	2004	2005	2006	2007	2008	2009
R&D staff	85	83	87	69	66	76

Source: Secretariat of the department

Research areas: Electrical Engineering consists of eight groups and five centres. **Groups:** Acoustic Technology (ACT), Automation and Control (AUT), Biomedical Engineering (BME), Electric Components (ELC), Electric Energy Systems (EES), Electromagnetic Systems (EMS), Electronics (ELE) and Hearing Systems (HEA). **Centres:** Automation Design Centre, Centre for Applied Hearing Research, Centre for Electric Technology, Centre for Fast Ultrasound Imaging and Centre for Playwear.

D: DTU Mathematics and Discrete Mathematics

	2004	2005	2006	2007	2008	2009
R&D staff	NA	NA	NA	NA	NA	9

Source: Secretariat of the department

Research area: At the Department of Mathematics, Discrete Mathematics is a core research and education priority and is divided into the following subfields: Error-correcting Codes and the fast transmission of information in a modern communication system known as Cryptology; disclosure of privacy and sensitive information, viruses, worms and spam. Graph Theory consists of the mathematical abstraction of networks such as transportation networks, road and railway networks, communication networks, molecular networks and social networks.

6. Copenhagen Business School

At the Copenhagen Business School, there are two departments and one centre which perform ICT research and development.

A: Centre for Applied ICT (CAICT)

	2004	2005	2006	2007	2008	2009
Research staff	NA	NA	NA	18	19	23

Source: Secretariat of the department

Research areas: Communications, Computer and Control Technology, Information Technology. User areas: Health, Transport & Mobility, Security, Independent Living & Social Inclusion, Green Technology. Instruments and Apparatus, Communications Systems – both mobile and wireless, Language Technology, Human-machine Interaction, including ease of use and involvement, Informatics, Embedded Systems/Pervasive Computing
Private R&D cooperation: The department has R&D cooperations with private firms in four projects.

B: Department of International Culture and Communication Studies

	2004	2005	2006	2007	2008	2009
Research staff	42	42	40	39	39	35

Source: Secretariat of the department

Research areas: Computer software, computer applications; User areas: business and administration, translation technology, knowledge management, language recognition. Technology enhanced learning.
Private R&D cooperation: The department has R&D cooperations with private firms in three projects.

C: Department of Informatics

	2004	2005	2006	2007	2008	2009
Research staff	24	24	25	18	15	15

Source; Secretariat of the department

Research areas: Computer software, general and management aspects, applications, handling and storage of very large data volumes, Embedded Systems/Pervasive Computing, methods for software development, human-machine interaction, including ease of use and involvement, Informatics.
Private R&D cooperation: The department has R&D cooperations with private firms in three projects.

3.1.2. The public R&D institutions in Scania

In Scania, there are four public institutions which perform ICT R&D. These are: The Faculty of Engineering, LTH, Lund University; outside the Faculty of Engineering, LTH, Lund University; Malmö University and Kristianstad University. Of these, the faculty of Engineering, LTH strongly dominates in public ICT research. In Scania as a whole, there has been the following development in the number of public ICT R&D staff.

Figure 3.3 Total number of public ICT R&D staff in Scania

	2004	2005	2006	2007	2008	2009
Lund University, outside the Faculty of Engineering	40	29	29	NA	26	20
Lund University, Faculty of Engineering, LTH	107	110	106	116	116	113
Malmö University	11	11	13	13	13	16
Kristianstad University	5	7	8	10	11	16
Total R&D staff	163	157	156	NA	166	165

Source: Secretariat of Faculty of Engineering, LTH and Secretariats of the departments

As the table shows, the ICT R&D staff has been relatively stable in the period from 2004-2009, with an increase of only 1.2%. In the following sections, we will present the ICT R&D fields and developments in the number of R&D staff at the various institutions that perform ICT R&D in Scania.

The Faculty of Engineering, LTH, Lund University

At the Faculty of Engineering, LTH, ICT research is performed at five departments.

A: Department of Electrical and Information Technology

	2004	2005	2006	2007	2008	2009
R&D staff	65	64	64	64	61	57

Source: Secretariat of Faculty of Engineering, LTH

Research areas: The research is organised into six different areas: *Circuits & Systems* focuses on tools and design for the construction of integrated circuits; *Communication* focuses on physical layer design, coding and modulation. *Networking & Security* focuses on system architecture and the security aspects of tele and data communications. Research in the area of *broadband* focuses on broadband access and core networks on all layers. A fifth area is *Electromagnetic Theory,* and the last area is various aspects of *Signal Processing.*

B: Department of Numerical Analysis and Scientific Computing

	2004	2005	2006	2007	2008	2009
R&D staff	5	5	5	5	6	5

Source: Secretariat of Faculty of Engineering, LTH

Research area: Among other things, the research focus is on the numerical analysis of multi-step methods and software for ODEs and DAEs, and the numerical analysis of differential equations, covering all aspects from theoretical analysis to applied problems and software construction.

C: Industrial Engineering and Automation, Department of Measurement Technology and Industrial Electrical Engineering

	2004	2005	2006	2007	2008	2009
R&D staff	10	11	9	9	8	9

Source: Secretariat of the department

Research areas: Most of the research at IEA is application oriented: *Electrical Drive Systems* offers a combination of problems in control structures, very fast digital control, power electronics, and machine design and operation. In *Electrical Power Systems,* the emphasis has been put on distribution automation, where control, computer engineering and power systems technology (including power electronics) have to be integrated. In Automation, the emphasis is on the control of industrial processes.
R&D cooperation: The department has co-operations in projects with 15 private firms. Of these, 12 are Swedish.

D: Department of Automatic Control

	2004	2005	2006	2007	2008	2009
R&D staff	13	14	13	13	14	15

Source: Secretariat of Faculty of Engineering, LTH

Research area: The research focus is on the following areas: *Modeling and Control of Complex Systems*, where theory and computer tools are developed to deal with fundamental complexity issues. *Control and Real-Time Computing* has a focus on networked embedded control, real-time techniques in control system implementation and control of real-time computing systems. *Process Control* within the pharmaceutical and chemical process industry and Robotics, with a focus on research in motion and compliance control, control system architecture and different sensor fusion problems.
R&D cooperation: Many of the projects are in an international cooperation. Cooperation with private firms such as ABB Robotics, Vestas Wind Systems, and Volvo Powertrain are common.

E: Department of Computer Science

The Department of Computer Science is on both the Faculty of Engineering, LTH and the Faculty of Natural Sciences at Lund University. Here, the research will be presented for both sections.

Department of Computer Science (Faculty of Engineering, LTH)

	2004	2005	2006	2007	2008	2009
R&D staff	14	16	15	25	27	27

Source; Secretariat of the department

Department of Computer Science (Faculty of Natural Sciences at Lund University)

	2004	2005	2006	2007	2008	2009
R&D staff	9	9	6	5	6	3

Source: Secretariat of the department

Research areas: Within the area of *Algorithms and Data Structures,* there is a focus on computational geometry, geometric graph algorithms, parallel distributed and sequential graph algorithms, computational biology, searching and sorting. Within *Computer Graphics,* central developing fields are new algorithms and the study of programming language and software architecture. *Embedded Systems Design* concentrates on various aspects of embedded computer system design, while *Robotics and Semantic Systems* combines semantic technologies with industrial automation, aiming at semantic systems. *Software Development and Environment* does experimental research on the development of new tools, languages and methods for software development. *Software Engineering* focuses on software platform management in product line engineering of embedded systems.

Lund University, School of Economics and Management, Lund University

Department of Informatics

	2004	2005	2006	2007	2008	2009
R&D staff	31	20	23	na	20	17

Source: Secretariat of the department

Research areas: The research is divided into three areas. *The Information Systems and Organisation Group* focuses on opportunities, problems and solutions at the intersection of information and communication technologies, information systems, management and organisations. *The Systems Construction Group* works on issues in the construction of software systems, primarily for business and administration, while the *Human-Computer Interaction Design Group* focuses on issues related to the digital environment, especially on everyday computing and interaction design.
R&D cooperation: There are project cooperations with private firms such as SCA and Trelleborg.

Malmö University

A: Department of Computer Science, School of Technology

	2004	2005	2006	2007	2008	2009
R&D staff	4	4	4	4	5	8

Source: Secretariat of the department

Research areas: These are within software techniques and systems, e.g. computing systems and architecture. Other fields are network infrastructure, software engineering, data management and digital content technologies. The ICT research is particularly directed towards the following user areas: health care, green IT, transport and mobility, and information security.

B: Department of Art, Culture and Communication

	2004	2005	2006	2007	2008	2009
R&D staff	7	7	9	9	8	8

Source: Secretariat of the department

Research areas: The research is oriented towards computer applications, digital content technologies, human technology interfaces and interactive design. The research is directed towards the following user areas: health, transport and mobility, independent living and social inclusion, experiences, entertainment and creative collaboration.
Research cooperation: The department has project collaborations with more than 20 private firms, including more than 10 foreign firms.

Kristianstad University

At Kristianstad University, ICT research is organised within two R&D groups placed at the School of Health and Society.

A: The Computer Science Group, School of Health and Society

	2004	2005	2006	2007	2008	2009
R&D staff	3	3	3	5	5	6

Source: Secretariat of the department

Research areas: The research is within communications, computer software and computer control technology. Important fields are also RFID (radio frequency identification in sensor-based networks), the Internet of things, embedded systems, systems-on-a-chip, systems-in-package (downscaling) and ICTs that enable scientific research. The research is focused on the following user areas: security, data communication and cloud computing.

B: The Informatics Group, School of Health and Society

	2004	2005	2006	2007	2008	2009
R&D staff	2	4	5	5	6	10

Source: Secretariat of the department

Research areas: The research area is the relationship between people and technology, and the design of that relationship. The group is working with the exploration of qualities and experiences that different ITdesigns offer. The group involves future users and other stakeholders in the design experiments, in which the group collaboratively envisions possible futures that IT can make come true. Foremost in the group is working with "IT with many users", including web design, social media, web 2.0, CSCW, etc. The group study and design technology in its context is something that often results in the group designing both the technology itself and the human action space

3.2 The development of ICT research students (PhD) in the Øresund Region

An important element in ensuring a high scientific level in the ICT sector is whether there is a transition of students from a general academic education to a research education in the Øresund region. This is not only important for ensuring a high level of research at the universities, but also for business. This is especially true within the ICT sector, where a large part of research and development is localised in firms. These firms are therefore very dependent on access to a highly skilled staff educated on the PhD level from the universities. In the following, we will investigate the number of enrolled and graduated PhD students at the universities in the Øresund region. The study is based on data from the institutions which is obtained directly from those who are responsible for statistics or from the managers of the institutions. If we look at the number of enrolled and graduated PhD students in the Øresund Region as a whole, we get the following number.

Figure 3.4 Number of enrolled and graduated students in the Øresund Region in 2009

	2009
Number of enrolled PhD students	508
Number graduated Ph D students	93

In the following section, we will see more in detail how the PhD students are allocated between Zealand and Scania.

3.2.1 PhD education in Zealand

In Zealand, there are six institutions which have the right to educate PhD students. These PhD educations are always an extension of already existing ICT education programmes. There is one educational institution, Aalborg University, which is located in Jutland that in recent years has established a new department on Zealand, which also has an ICT PhD program, albeit on a smaller scale. The institution which has the most ICT PhD education is the Technological University of Denmark, which educates 62% of all PhD students within ICT in Zealand.

Figure 3.5 PhD education institutions in Zealand in 2009

	Number of students on PhD level	Graduates on PhD level
Copenhagen Business School (CBS)	18	8
Technological University of Denmark	234	41
IT University of Copenhagen	46	20
University of Copenhagen	61	9
Roskilde University	11	1
Aalborg University: Copenhagen Ballerup Campus	7	NA
Total PhDs Zealand	377	79

Source: Statistics from institutions

3.2.2. PhD education in Scania

In Scania, Lund University is the only institution allowed to conduct PhD exams. This does not mean that a PhD student cannot be located at another institution. Such is often the case with, for example, Malmö University, which has PhD students placed at their institution. In this investigation, the PhDs are placed where they are registered. In the following figure, the development of enrolled and graduated PhD students in Scania for the period from 2004-2009 are shown:

Figure 3.6 - Total number of enrolled and graduated ICT PhD students in Scania from 2004-2009

PhDs in Scania	2004	2005	2006	2007	2008	2009
Enrolled PhD students	166	162	157	144	131	131
PhD exams	15	23	21	22	10	14

Source: Secretariat of the Faculty of Engineering, LTH and Secretariats of departments

For the most part, we can here see that the number of graduated ICT students in Scania has been stable during this period. The number of enrolled ICT students has, however, decreased by 21.1%. If we look at the distribution between enrolled and graduated students between institutions in Scania, we get the following picture.

Figure 3.7 Number of enrolled and graduated ICT PhD students at educational institutions in Scania in 2009

	Number of enrolled PhD students	Number of graduated PhD students
Faculty of Engineering, LTH	107	9
Lund University, outside the Faculty of Engineering	24	5
Total in Scania	131	14

Source: Secretariat of Faculty of Engineering, LTH and Secretariats of departments

Here, we see a strong domination from the Faculty of Engineering, especially concerning enrolled PhD students. The Department of Electrical and Information Technology is the clear leader, with 49 enrolled ICT PhD students (See appendix III).

Chapter 4

The educational structure

4.1 The ICT educational structure in the Øresund Region

The educational structure is a vital precondition for securing a qualified workforce to ensure a high level of skill within the ICT sector. It is not just about ensuring a high professional level, but also to ensure fundamental basic skills that allow for further training and upgrading of previously secured academic and social skills. These framework conditions are important in an industry characterised by innovation, development and global cooperation. The development of the Øresund Region is based on a labour force and education system localised in two national territories. However, they are closely related both linguistically and culturally, which means in reality that their education systems are also closely related. In addition, the EU context has also implied a closer correspondence with the European educational system structure which the two countries are a part of.

The education system is supported by a growing integration of the labour forces of the two national parts of the Øresund region. The total number of persons who commute each day between the two parts amounts to approximately 20,000, with that number constantly increasing.

If we look at the educational structure in the Øresund region, there is a total of 13 universities and colleges[9] which have ICT education at an academic level, including undergraduate as well as master studies. This includes "pure" ICT programs among a wide range of other programmes, which to a varying extent includes ICT and where ICT is a component of the education system. Because of this, the variation ranges from pure technical education to more information technology programmes. The education can therefore be both a social science and humanistically-based one in addition to being technical. The point of departure for this investigation has been that at least 90 ECTS must consist of pure ICT for the program to be defined as an ICT education.

With this definition, we obtain the following number of enrolled and graduated ICT students in the Øresund Region:

Figure 4.1 Total number of enrolled and graduated ICT students in the Øresund Region between 2004-2009

	2004	2005	2006	2007	2008	2009
Total numbers of enrolled students	NA	7,598	7,541	7,683	7,780	8,413
Total number of graduated students	1,431	1,567	1,409	1,455	1,408	1,414

The figure reveals that there have been different development tendencies in the total number of enrolled students and graduated students. Concerning the amount of ICT students, there has been a 10.7% increase in the period from 2005-2009, with 8,413 ICT students in the Øresund region in 2009, including 1,414 graduates, which was actually a decrease of 1.2% in the period from 2004-2009. These numbers for the Øresund Region as whole, however, cover different development tendencies in the two national parts of the region, which will be shown in the following sections.

9. The Faculty of Engineering, LTH and Campus/Helsingborg have been registered as separate institutions, but both belong to the University of Lund.

4.2. Development of ICT educational structure on Zealand

On Zealand, there are seven universities and one university college that supply ICT education on an academic level. These are the University of Copenhagen, Aalborg University Ballerup, Denmark's Technical University, Roskilde University, the Copenhagen Business School, the University of Southern Denmark: Campus Slagelse, the IT University of Copenhagen and the Copenhagen University College of Engineering. These institutions will often have more than one programme in ICT. But there is often a pure ICT program at an institution and ICT is often integrated into other education programmes as well. There is a clear trend that ICT is spreading and becoming an important element in more traditional programs such as economics, communications, etc., not only as a supplementary tool, but also as pure ICT skills.

In Zealand, there were 5,772 students enrolled in an academic ICT program in 2009, including a bachelor's or master's program, and 1,119 of these students left these programs with an exam. In Zealand, there was also an increase in the number of enrolled ICT students in the period from 2005-2009, which amounted to 7.5 %, and an increase in the number of graduated ICT students from 2004-2009 that amounted to 14.5%.

Figure 4.2 Total number of ICT students in Zealand from 2004-2009

	2004	2005	2006	2007	2008	2009
Total number of enrolled students	NA	5,371	5,400	5,462	5,465	5,772
Total number of graduated students	977	1,118	1,018	1,129	1,067	1,119

To see how the students are divided in terms of educational institutions and programmes on the Zealand side of the region, see Appendix III.

Figure 4.3 Number of enrolled and graduated ICT students divided into education institutions in Zealand in 2009

ICT education institutions in Zealand	2009
1.Technological University of Denmark	
Number of students enrolled in ICT programs	1,632
Number of graduated ICT students	352
Programmes: See Appendix 1	
2. IT University of Copenhagen	
Number of students enrolled in ICT programs	1,705
Number of graduated ICT students	257
Programs: master's in IT, bachelor's in IT	
3. University of Copenhagen	
Number of students enrolled in ICT programs	1,030
Number of graduated ICT students	147
Programs: master's in IT, master's in Bioinformatics, bachelor's in IT, master's in e-Science	

4. Copenhagen Business School	
Number of students enrolled in ICT programs	627
Number of graduated ICT students	144
Programs: Bachelor HA (it), Bachelor HA (im) Information Management, Cand.merc. (it)	
5. Copenhagen University College of Engineering	
Number of students enrolled in ICT programs	238
Number of graduated ICT students	90
Programs: bachelor's program	
6. Roskilde University	
Number of students enrolled in ICT programs	158
Number of graduated ICT students	62
Programs: Bachelor's and Master's programs in Computer Science and Informatics	
7. Aalborg University/Copenhagen, Ballerup Campus	
Number of students enrolled in ICT programs	349
Number of graduated ICT students	39
Programs: bachelor's in Medialogy, master's in Medialogy, master's in Innovative Communication and Entrepreneurship	
8. University of Southern Denmark: Slagelse Campus	
Number of students enrolled in ICT programs	33
Number of graduated ICT students	28
Programs: bachelor's in Economics and Information Technology	
Total number of students enrolled in ICT programs	**5,772**
Total number of graduated ICT students	1,119

1. Technological University of Denmark

This is one of the largest educational institutions in the ICT field in Zealand, with 352 graduating students in 2009. There are six programs at the undergraduate level and five master's programs.

Bachelor's programs:

On *The Bachelor of Engineering* level there are three programs: *Bachelor of Engineering (IT Engineering)* – the study includes both computer science and software engineering, electronics and embedded systems; *Bachelor of Engineering (Internet technology and Business Economy)* – the study provides technical and professional skills such as IT programming, Communication Technology, IT and Organization, and User Interfaces, which is supplemented with a range of subjects from HA studies at CBS in Copenhagen; *Bachelor of Engineering (Electrical and Electronic Engineering)* – This is an education in electronic design, electrical energy systems, wireless communications, industrial systems, medical electronics and digital signal processing.

The Bachelor of Science in Engineering (BSc) Program also has three programs with a *(BSc) in Software Engineering*. This program includes: Algorithms and Data Structures Software Engineering, Embedded Systems, Computer Science Modelling, Computer Architecture, etc. The *(BSc) Bachelor of Science in Engineering (IT and communication technology)* includes Human-machine interaction, IT-supported Communication, Software, Engineering, Algorithms and Data Structures, Digital Electronics, etc. The *(BSc) Bachelor of Science in Engineering (Electrical Engineering)* includes digital and analog electronics, programming, electromagnetism and microprocessors.

Master's programmes: Master of Science in Engineering (MSc)

On the master's level, there are five programs: *(MSc) Master of Science in Engineering (Computer Science and Engineering)* deals with computer science, computer engineering, mathematics, logic, systems engineering and project management. *(MSc) in Mathematical Modeling and Computation* includes applied mathematics and mathematical modelling as well as modern computer equipment and the handling of large volumes of data. *(MSc) in Telecommunications* is about the internet, software design, and signal or transmission technology. *(MSc) in Digital Media Engineering* gives knowledge in areas such as user interfaces and user interaction, networking and mobile technology, computer graphics, software engineering, software prototyping tools, mathematical modelling and numeric and optimization. *(MSc) Master of Science in Engineering (Electrical Engineering):* This program includes electrical and electronic components, circuits and networks, signal processing, control, regulation, embedded programming, electromagnetism and field theory, and electrical energy and power.

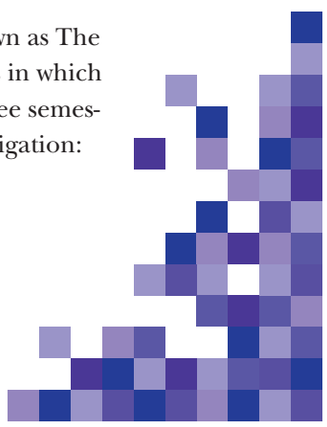
There is also a new degree program: *(MSc) Master of Science in Engineering (Digital Media Engineering).* This course is about technologies for interactive digital media and refers specifically to the development of computer games and other end-user applications that use 3D graphics, in addition to internet technologies and new forms of mobile interaction, personalized interfaces adapted to the context and user preferences.

2. IT University of Copenhagen

The second largest IT educational institution on the Zealand side is the IT University of Copenhagen, which specializes in IT education and research. The university offers education in English and Danish, including undergraduate and master's degrees, as well as a PhD student programme. They offer a bachelor's degree within the fields of Global Business Informatics, Digital Media and Design, Software Development and a Master of Science within IT, Software Development and Technology, Media Technology and Games, IT and Business (E-business), and Digital Design and Communication.

3.University of Copenhagen

At the University of Copenhagen, there is a large ICT education department known as The Department of Computer Science, but there are also a number of other programs in which ICT is included as an essential element. But with our criteria of having at least three semesters of pure ICT education, the following programs are not included in this investigation: Geography & Geoinformatics, Science and IT.



At the *Department of Computer Science,* the bachelor's education program is based on an introduction to Computer Architecture, Algorithmics, Databases, Networks and Operational Systems, whereas the master's program is based on Advanced Programming, Principles of Computer Systems Design, Statistical Methods for Machine Learning, Advanced Algorithms and Data Structures. At the *Bioinformatics Centre* there is a master's programme in bioinformatics. The programme is based on students with a mathematical background (computer science, physics, statistics, math, engineering, etc.) who want to work with very challenging computational problems, using real data with large computational power and students from the *life sciences* (biology, chemistry, medicine, etc.) who want to use computers to solve biological problems.

e-Science includes the following compulsory courses: Scientific Computing, Statistics for e-Science, Scientific Visualization and Scientific Data Management, as well as limited elective course methods and techniques and a master´s thesis. In 2009, there were 1,030 students enrolled in IT programmes at the University of Copenhagen.

4. Copenhagen Business School

This is basically an international school focusing on developing strong links between contemporary research and the active business community. The ICT education is divided into various programs, with 627 students in 2009.

The Bachelor's Programme in Business Administration and Information Systems is a business economic program, which combines economics, informatics and organization theory. *The BA in Information Management* integrates information, communication and technology and prepares for a career in a rapidly changing global business environment.

The master's program is an *MSc in Business Administration and Information Systems* and is a two-year program that focuses on the intersection of information systems with organization, strategy and management.

5. Copenhagen University College of Engineering

This educational institution is located in the Copenhagen area in Ballerup. The Engineering College is in a close cooperation with Aalborg Universities' Copenhagen department, which is also located at the same address.

The Bachelor in Information and Communication Technology includes the disciplines of electronics and information technology, with a focus on user and development-oriented skills in information technology, electronics engineering, machine construction and telecommunications.

The study of the BSc Programme in Electronics Computer Engineering includes several courses and projects within a number of disciplines such as digital signal processing, object-oriented programming, digital electronics and computer networks.

6. Roskilde University

The university offers studies at both the bachelor and master level in Computer Science and Informatics. Problem-oriented project work is especially emphasised since it is an important element in the academic disciplines at Roskilde University, including computer science.

The bachelor's module focuses on the construction and development of computer software.

The master's level focuses on computer-based technologies, and the key objective is to endow the student with a deeper understanding of a specific technology as well as the general principles that sustain such a technology. *The Informatics Programme* is based on an evaluation of IT applications, IT security, IT strategy and the application of IT within the domain-specific disciplines, including HCI – Human-Computer Interaction.

7. Aalborg University/Copenhagen: Ballerup Campus

The campus in Ballerup near Copenhagen is a branch of Aalborg University in Jutland and closely linked to the Engineering College of Copenhagen also located in Ballerup. The education program includes a *bachelor's and master's in Medialogy (BSc and MSc).* The education is based on studies of human and computational perceptions, audio visual effects, animation and computer games, and immersive systems and computing communications, and there is also a new master's in *Innovative Communication and Entrepreneurship,* which is about communication and broadcast technologies described as Services and Platforms; Development of user friendly applications and solutions; Business development and models; Security, confidentiality and legal/ethical aspects; Use of IT and communication technologies in enterprises and organizations. A new bachelor's in *IT, Communication an; Media Technology* has just opened in 2010. It is an education on; New mobile network technologies; Development of mobile applications; User-friendly solutions and services; Economic and business development; and Use of ICT by businesses and organizations.

8. University of Southern Denmark: Slagelse Campus

This institution is a merger of the former business school in Slagelse and a new department of the University of Southern Denmark. The University of Southern Denmark is an institution with many different localities in Denmark, primarily on Funen and Jutland, but now also on Zealand. In Zealand, there is only one ICT related educational program; *Bachelor in Economics and Information Technology.* This bachelor's programme includes professional elements such as Software Project Management, Web Application Development, IT Strategy in Business, Database Design and Applications, Systems Development, and Organisational Theory and Economics.

4.3 The ICT education structure in Scania

In Scania there are five public institutions that supply ICT education on an academic level. These are the Faculty of Engineering, LTH; Lund University; the faculty outside the Faculty Engineering at Lund University, Campus Helsingborg; Malmö University; and Kristianstad University. The Faculty of Engineering and Campus Helsingborg are part of Lund University. In turn, each of these institutions has several different programs within the field of ICT. ICT has spread today into almost every academic field. Here, we will focus on the more "pure" ICT field, which implies that an education in which ICT is simply implemented is not part of the definition of an ICT education, which also is in accordance with our OECD definition of the ICT field.

In 2009, there were 2,641 ICT students on academic ICT programs in Scania who had at least three semesters of ICT education, and the number of graduating students was 295. If we look at the development of enrolled ICT students in Scania, the increase in the period from 2004-2009 was 7.7%, while there was a sharp decrease in the number of students who graduated in the same period that amounted to a 35% drop. This stands in sharp contrast to Zealand, where there was an increase during the same period.

Figure 4.4 The total number of enrolled and graduated ICT students in Scania from 2004-2009

	2004	2005	2006	2007	2008	2009
Total number of enrolled students	2,452	2,227	2,141	2,221	2,315	2,641
Total number of graduated students	454	449	391	326	341	295

For a more detailed description of how the students are divided into the following educational institutions and programs in Scania, see Appendix III.

Figure 4.5 Number of enrolled and graduated ICT students divided into education institutions in Scania 2009

ICT Educational Institutions in Scania	2009
1. Faculty of Engineering LTH, Lund University	
Number of enrolled students in ICT programs	1,291
Number of graduated ICT students	173
ICT programs: master's programs, international two-year master's programs	
2. Campus Helsingborg, Faculty of Engineering, Lund University	
Number of enrolled students in ICT programs	118
Number of graduated ICT students	9
ICT programs: Bachelor of Science programs	
3. University of Lund outside Faculty of Engineering	
Number of enrolled students in ICT programs	320
Number of graduated ICT students	47
ICT programs: bachelor's, master's (one year)	
4. Malmö University	
Number of enrolled students in ICT programs	507
Number of graduated ICT students	21
ICT programs: bachelor's, master's (one year)	
5. Kristianstad University	
Number of enrolled students in ICT programs	405
Number of graduated ICT students	45

ICT programs: Bachelor of Science, master's (one year), diploma (two years)	
Total number of enrolled students in ICT programs in Scania	**2,641**
Total number of graduated ICT students	295

1. Faculty of Engineering, LTH

The Faculty of Engineering, LTH is part of the University of Lund and is the largest of the institutions that supplies an ICT education in Scania, with 1,291 enrolled students and 173 students who graduated in 2009. There are three five-year master's programs at the Faculty of Engineering, LTH. The program in *Computer Science* starts with three basic years, where an important field is embedded systems. The last two years are for specialisation in, for example, pictures and graphics, the design of processes and digital systems, communication systems and software. In the program *Electrical Engineering*, there is focus on the measuring, handling and transferring of signals in addition to programming and using simulation tools. The last part of the program is for a specialisation in energy and the environment, photonics and communication systems. The last of the five-year master's programs is *InfoCom*. Like the other programs, it starts with three years of obligatory courses in programming, mathematics and how modern communication systems function. The last two years specialise in usability and design, in addition to modern communication systems.

There are also three two-year international master's programs. *The Photonics Programme* focuses on three major areas of photonics: engineering, communication and diagnostics. The program *System-on-Chip* focuses on integrating wireless and wired communication electronics, utilising the next revolution in microelectronics and System-on-Chip design. The program *Wireless Communication* focuses on the physical and lower level of wireless communication in which the aim is to give deep system knowledge, which in turn requires insight into the various components of a wireless system.

2. Campus Helsingborg/Faculty of Engineering, Lund University

This institution is part of The Faculty of Engineering, LTH but is located in Helsingborg. There were 117 students enrolled in ICT programs and nine who graduated on the bachelor's level.

There are two ICT bachelor's programs. *The Programme in Computer Science* focuses on computer systems such as software, hardware and the technological interface with the environment in which the computer systems shall be used. *The Programme on Electrical Engineering* focuses on project engineering, construction, maintenance and the operation of automation and electrical plants, of which both hardware and software are part and where electrical and automation techniques as well computer technology are required.

3. Lund University

At Lund University, there are of course many departments which have ICT education in some form, not least with the implementation and application of ICT. As per our definition of ICT education, which is at least three semesters of pure IT education, only two departments at Lund University have had IT education in the period from 2004-2009. Until 2007, the *Department of Computer Science* had educational programs at the Lund University Faculty of Natural Science and the Faculty of Engineering Science, LTH. After 2007, the education

at the department was integrated into the Faculty of Engineering's programs. Thus, the only department left at Lund University that has an ICT education according to our definition is the *Department of Informatics* at the School of Economics and Management, where there is a *bachelor's programme in the Design of Information Systems* in which a central issue is how information systems and ICT can be developed and designed to create value for both companies and society. In *the master's programme in Information Systems,* which is a one-year program after the bachelor's degree, the student shall acquire a deeper understanding and knowledge of important facets of Information Systems, Information Design and Information Communication Technology. In 2009 in these two departments, there were 320 students enrolled in ICT programs and 47 graduating students.

In 2010, a master's program in Bioinformatics will be established at the Department of Biology.

4. Malmö University

There were 507 students enrolled in the ICT programmes at Malmö University in 2009 and 21 graduated within ICT programs in the same year. The university is known as a professional university where the focus is on interdisciplinary education and research. The ICT programs are primarily placed at *The School of Technology,* but there is also ICT education within the *Department of Art, Culture and Communication*. Most of the programs in the latter do not come to the three semesters of pure IT education, which is our definition of an ICT education. In the School of Technology, where the aim is to integrate natural science, technology and social science perspectives, there are many ICT programs at the Department of Computer Science. Up to now, the programs have been on the bachelor's level. You can choose from among the following programs: *Computer and Telecom: Technology and Management, the Bachelor Programme in Computer and Telecom Engineering: Technology and Management, System Developers, and Information Architect*. In 2010, a one-year Master Programme in Computer Science will be started. In the Department of Art, Culture and Communication, there is a bachelor's and master's program in Interactive Design.

5. Kristianstad University

Kristianstad University is organized into two sections where both education and research take place. These sections are the School of Health and Society and the School of Teacher Education. The ICT education belongs to the former section and is placed under the *Department of Computer Sciences*. The programs range from two-year diploma programs to bachelor and master programs. There are bachelor's programs in *Computer Software Development, Electronics and Computer Engineering and Interactive Sound Design*. In 2010, there will be a new *Bachelor Programme in Digital Design* under the Informatics group. *The Master Programme with a Specialization in Embedded Systems* is a one-year program, which requires a bachelor's degree within ICT. There were 405 students enrolled in ICT programs in 2009 and 45 of them graduated.

4.4. Other ICT studies on the Business Academy education level (KVU)

In Zealand it has been possible to acquire aggregated statistics in relation to the number of ICT students on the business academy level (KVU), though this has not been possible to do for Scania. Despite this, we have chosen to bring the statistical data for Zealand, as Zealand constitutes the most substantial part of the ICT sector in the Øresund Region. The ICT Business Academy education programs also play an important role in the ICT sector's qualification structure. That educational structure will not be examined in detail here, but those statistics can be found in Appendix III.

Figure 4.6 - The number of graduated students from 2001-2008 in Business Academy ICT education programs in Zealand

	2001	2002	2003	2004	2005	2006	2007	2008
Other ICT education	103	58						
Computer Science	535	687	597	454	261	206	129	87
IT and Electronics		32	44	40	38	18	25	39
Multimedia Design		470	560	357	290	257	273	277
Total	638	1,247	1,201	851	589	481	427	403

Sources: statweb.uni-c.dk/databanken/uvmdataweb

There is a low completion percentage in ICT Business Academy education. It is only 43% for Computer Science, 55% for IT and Electronics and 58% for Multimedia Design programmers. This can be compared with Shorter Higher Education (KVU) programmers in general, in which the completion rate was 72% in 2009.

Conclusion

The ICT industry is by far the most R&D intensive industry, measured in both R&D expenditure and employment. Having strong R&D resources is therefore a decisive factor in terms of the competitive power of ICT firms.

There is also an increased globalization of business R&D, which is facilitated by the technology itself as well as by programs for organizations such as the EU. An important incentive for this globalization is to globally exploit available skills.

The United States is in the clear lead concerning ICT research with a 72% larger ICT than the EU-15, which in turn is slightly ahead of Japan if we look by sector at the increase in R&D expenditures during the period from 1996-2005. Computer and related activities is the strongest growing sector, with a tripling of its R&D expenditures. In addition, the telecom sector has experienced a strong increase in R&D expenditures. Denmark is among the countries with the largest share of ICT business in total R&D personnel in Europe at 39%, with only Ireland and Finland ahead at 54% and 51%, respectively (OECD, 2008).

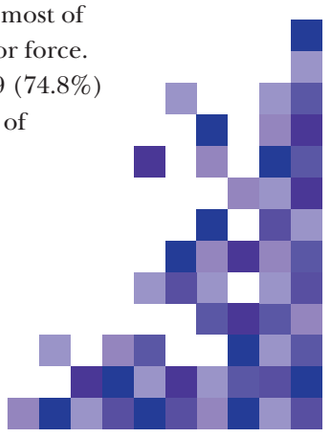
A characteristic for ICT firms is that most of the R&D in these firms is conducted within the firms, which means that access to R&D skills within the firm is of the utmost importance as far as their competitiveness. If we look at the Øresund Region in 2007, the total number of R&D staff in ICT firms was 13,033 with 10,930 located on Zealand and 2,095 located in Scania. This can be compared with Stockholm, where the R&D staff was 8,782 for the same year. If we look instead at expenditures on R&D, there was an investment of EUR 1,140,110 in the Øresund Region in 2007 compared to Stockholm's EUR 1,133,730, which is about the same.

It is important to bear in mind here that 20% of ICT research in Denmark is performed outside the ICT sector.

Concerning both ICT R&D staff and expenditure on ICT R&D, there was an increase from 2005-2007 in the Øresund region. Nevertheless, this covers the fact that there was a decline in Zealand in both ICT R&D expenditures and employment for the same period.

If we look at the collaboration pattern and from where ICT firms buy their R&D, we find a strong dominance of "other firms", meaning firms outside the firm's own group. On Zealand, which is the only geographical area where it was possible to obtain R&D statistics at this level, 78% of the suppliers were "other firms". This can be compared with universities and other public institutions, which only supplied 1.2% of the ICT firms R&D on Zealand. This weak cooperation has also been supported by other Danish investigations, thereby possibly indicating that public research plays a very small role in the development of innovation and the competitive power of ICT firms. Although direct cooperation between ICT firms and universities and public institutions is restricted, good framework conditions in the form of public R&D are important. Spin-off firms from public R&D are one example where public R&D is important, but provide a high level of research is also important for the quality of education. This is particularly important for ICT firms that conduct most of their innovations in-house and are therefore dependent on a highly educated labor force.

In 2009 in the Øresund Region, there were 654 public ICT researchers, with 489 (74.8%) on Zealand and 165 (25.2%) in Scania. On Zealand, the Technological University of



Denmark strongly dominates public ICT research, with 280 researchers (57.3%) of the total public R&D researchers on Zealand. This can be compared with the second largest, which is the IT University of Copenhagen with 62 researchers. In Scania, we find the same pattern with technical university; in this case, the Faculty of Engineering, LTH, totally dominates in R&D research with 113 researchers, which constitutes 68.5% of all public ICT R&D researchers in Scania.

Framework conditions in the form of a strong PhD education are especially important for the ICT sector, which to large degree is dependent on their own R&D and a supply of an R&D staff educated at the top level. In the Øresund region in 2009, there were 508 ICT students enrolled on the PhD level and 93 graduated. Of the total number of students enrolled, 377 were in Zealand, which constitutes 74.2%, while 79 graduated on Zealand, which constitutes a share of 84.9%. In Scania 131 ICT PhD students were enrolled, which constitutes 25.8% of the Øresund region's total number of ICT PhD students. In Scania, there were 14 ICT students who graduated, which constitutes 15.1% of those who graduated in the Øresund Region. We can see the same pattern here as within ICT researchers, which implies a very strong position within ICT education for technical universities on both sides of the sound, thus strongly dominating ICT PhD education in the Øresund region.

In 2009, the total number of enrolled ICT students on the academic level in the Øresund Region was 8,413 students in addition to 1,924 from the business academy level on Zealand. The total number of students who graduated on the academic level was 1,414 as well as 403 ICT students from the business academy level on Zealand. If we look at the development of enrolled ICT students in the Øresund region for the period from 2005-2009, there was an increase of 10.7%. The number of graduated ICT students did not catch up with this trend, and on the whole was stagnant during the period from 2004 – 2009, with a decrease of 1.2%.

These aggregated numbers cover large differences in development tendencies in the two national parts of the region for the period under investigation period. In Zealand, there was an increase in both enrolled and graduated ICT students. In Scania, however, there has been a dramatic fall of 35% in the number of graduated ICT students in the same period, which constitutes one of the most important challenges for the ICT sector on the Scanian side.

If we look at the educational structure within ICT in Zealand, we can see a differentiation of the various ICT programs with more specialization and adaptation to different fields, which can be part of the reason for success.

Appendix I - R&D Institutions

ICT R&D resources in public institutions, Zealand

1. IT University of Copenhagen

R&D Staff	2004	2005	2006	2007	2008	2009
Number	48	46	45	47	54	62
Divided into research groups from 2007-2009						
Efficient Computation				3	3	4
Design of Organisational IT				4	9	11
Software Development Group				7	6	9
Computer Games Research				20	12	13
Innovative Communication				7	8	8
Programming, Logic and Semantics				3	13	10
Digital Culture and Mobile Communication				3	3	7

Source: Secretariats of the department

Appendix II

PhD students in the Øresund Region

Universities on Zealand, PhD	2004	2005	2006	2007	2008	2009
Copenhagen Business School (CBS)						
PhD informatics						
Students on PhD level	14	12	16	16	17	13
Graduated on PhD level	3	2	1	3	0	6
PhD in Computational Linguistics						
Students on PhD level	4	5	5	4	3	5
Graduated on PhD level	0	0	0	2	1	2
Technological University of Denmark (DTU)						
Electronic Engineering						
Students on PhD level	38	43	46	51	50	67
Graduated on PhD level	10	10	6	13	11	11
Photonics Engineering						
Students on PhD level	60	56	50	53	55	65
Graduated on PhD level	10	18	16	12	14	8
Informatics						
Students on PhD level	58	64	73	86	74	87
Graduated on PhD level	18	14	13	16	16	18
Discrete Mathematics						
Students on PhD level	11	13	15	17	16	15
Graduated on PhD level	0	1	4	2	4	4
IT University of Copenhagen						
Total Students on PhD level	44	44	44	38	39	46
Total Graduated on PhD level	12	10	11	10	15	20

University of Copenhagen						
Department of Computer Science						
Students on PhD level	15	14	20	35	48	42
Graduated on PhD level	2	4	3	2	11	8
Centre for Language Technology (IT)						
Students on PhD level	0	1	1	0	0	0
Graduated on PhD level	0	0	0	1	0	0
Centre of e-Science						
Students on PhD level	0	0	0	0	6	13
Graduated on PhD level	0	0	0	0	0	0
Bioinformatic Centre						
Students on PhD level	0	0	1	2	4	6
Graduated on PhD level	0	0	0	0	0	1
Roskilde University						
Students on PhD level	9	10	10	11	11	11
Graduated on PhD level	0	4	1	2	2	1
Aalborg University Copenhagen, Ballerup Campus						
Students on PhD level	0	0	6	8	7	7
Graduated on PhD level	0	0	0	0	0	NA

Source; Secretariats of the departments

PhD students in Scania

ICT PhD and Lic. in Scania	2004	2005	2006	2007	2008	2009
Faculty of Engineering, LTH, Lund University Dept. of Electrical and Information Technology						
Students on PhD level	64	57	59	58	49	49
Graduated on PhD level	9	9	6	12	1	3
Graduated on Lic. Level	7	6	4	2	1	3
Dept. of Numerical Analysis and Scientific Computing						
Students on PhD level	5	5	5	1	1	4
Graduated on PhD level	0	0	4	0	0	0
Graduated on Lic. Level	0	1	0	0	0	0
Industrial Engineering and Automation						
Students on PhD level	13	16	11	12	12	13
Graduated on PhD level	1	6	1	0	1	1
Graduated on Lic. Level	2	3	1	2	0	4
Dept. of Automatic Control						
Students on PhD level	23	23	24	23	23	24
Graduated on PhD level	2	3	3	5	2	3
Graduated on Lic. level	2	3	3	0	0	0
Dept. of Computer Science						
Students on PhD level	24	24	22	19	18	17
Graduated on PhD level	1	3	5	2	2	2
Graduated on Lic. level	3	1	2	2	1	1
Total for Faculty of Engineering, LTH						
Students on PhD level	129	125	121	113	103	107
Graduated on PhD	13	21	19	19	6	9
Graduated on Lic. level	14	14	10	6	2	8

Source: Secretariat of Faculty of Engineering LTH and Secretariats of the departments

Lund University (outside Engineering Faculty)	2004	2005	2006	2007	2008	2009
Department of Informatics						
Students on PhD level	28	28	27	25	23	21
Graduated on PhD level	0	2	0	2	3	2
Graduated on Lic. level	0	0	0	0	0	0
Department of Computer Science (nat. fac.)						
Students on PhD level	9	9	9	6	5	3
Graduated on PhD level	2	0	2	1	1	3
Graduated on Lic. level	0	0	0	0	0	0
Total for Lund University						
Students on PhD level	37	37	36	31	28	24
Graduated on PhD level	2	2	2	3	4	5
Graduated on Lic. level	0	0	0	0	0	0

Source: Secretariats of the departments

Total number of enrolled PhD and graduated PhD and Lic. in Scania

	2004	2005	2006	2007	2008	2009
Students on PhD level	166	162	157	144	131	131
Graduated on PhD level	15	23	21	22	10	14
Graduated on Lic. level	14	14	10	6	2	8

Appendix III – ICT education in the Øresund Region

1. Technological University of Denmark

Technological University of Denmark: Bachelor of Engineering (BEng)	2004	2005	2006	2007	2008	2009
Bachelor of Engineering (IT Engineering)						
Students on bachelor's level	423	412	354	319	304	261
Graduated on bachelor's level	3	57	97	69	57	58
Bachelor of Engineering (Internet Technology and Business Economy)						
Students on bachelor's level	0	0	21	34	54	69
Graduates on bachelor's level	---	---	----	---	---	2
Bachelor of Engineering (Electrical and Electronic Engineering)						
Students on bachelor's level	343	305	291	268	264	265
Graduates on bachelor's level	90	84	47	46	36	40
Total for Bachelor's of Engineering						
Number of students on bachelor's level	766	717	666	621	622	595
Number of graduated students on bachelor's level	93	141	144	115	93	100
Bachelor of Science in Engineering (BSc) BSc in Software Engineering						
Number of students on bachelor's level	54	121	177	215	214	214
Number of graduated students on bachelor's level				9	42	38
BSC Bachelor of Science in Engineering (IT and communication technology)						
Number of students on bachelor's level	13	35	44	51	68	92
Number of graduated students on bachelor's level				1	9	11

BSc Bachelor of Science in Engineering (Electrical Engineering)						
Number of students on bachelor's level	68	109	149	184	192	173
Number of graduated students on bachelor's level			1	15	33	44
Total at the bachelor's level						
Total number of students	135	265	370	450	474	479
Total number of graduated students	--	--	1	25	84	93
Master of Science in Engineering (MSc)						
MSc Master of Science in Engineering (Computer Science and Engineering)						
Number of students on master's level	--	---	---	56	120	124
Number of graduated students on master's level	27	33	32	30	56	48
MSc in Mathematic Modelling and Computation						
Number of students on master's level	----	---	----	----	58	110
Number of graduated students on master's level	20	30	30	26	22	20
MSc in Tele Communication						
Number of students on master's level				127	99	116
Number of graduated students on master's level	15	14	23	12	15	33
MSc in Digital Media Engineering						
Number of students on master's level	----	-----	-----	----	10	33
Number of graduated students on master's level	-----	------	------	----	0	0

MSc Master of Science in Engineering (Electrical Engineering)						
Number of students on master's level				52	110	175
Number of graduated students on master's level	45	46	67	67	59	58
Total for MSc						
Number of students on master's level	NA	NA	NA	235	397	558
Number of graduated students on master's level	107	123	152	135	152	159
Total for Technological University of Denmark						
Total number of ICT students	901	1,105	1,188	1,306	1,493	1,632
Total number of graduated ICT students	200	264	297	275	329	352

3. IT University of Copenhagen

IT University Copenhagen	2004	2005	2006	2007	2008	2009
Bachelor's in IT						
Number of students on bachelor's level	---	---	---	42	76	190
Number of new enrolled students on bachelor's level	---	---	---	42	47	124
Number of graduated students on bachelor's level	---	---	---	---	---	----
Master's in IT						
Number of students on master's level	989	1,044	1,076	997	910	878
Number of new enrolled students on master's level	302	381	319	277	266	335
Number of graduated students on master's level	220	265	208	295	237	205
Part-time Bachelor's in IT						
Number of students on master's level	168	252	237	249	252	275
Number of new enrolled students on master's level	41	50	51	42	48	52
Number of graduated on master's level	9	17	8	9	13	18

Part-time Master's in IT						
Number of students on master's level	169	270	247	276	283	362
Number of new enrolled students on master's level	39	38	76	61	79	117
Number of graduated students on master's level	6	16	9	16	34	34
Total for IT University Copenhagen						
Total number of students enrolled	1,326	1,566	1,560	1,564	1,521	1,705
Total number of graduated students	235	298	225	320	284	257

4. University of Copenhagen

Department of Computer Science	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Bachelor's in IT						
Number of students on bachelor's level	---	741	673	623	593	616
Number of new enrolled students on bachelor's level	163	88	76	103	86	NA
Number of graduated students on bachelor's level	91	96	106	70	67	66
Master's in IT						
Number of students on master's level	---	372	404	409	410	370
Number of new enrolled students on master's level	93	105	108	59	53	
Number of graduated students on master's level	37	42	43	53	60	78
The Bioinformatics Centre						
Master's in Bioinformatics						
Number of students on master's level	28	39	39	37	25	33
Number of graduated students on master's level	0	5	6	11	11	3

e-Science Centre Master's in e-Science						
Number of students on master's level	0	0	0	0	0	11
Number of graduated students on master's level	0	0	0	0	0	0
Total number of students	NA	1,152	1,116	1,069	1,028	1,030
Total number of graduated students	128	143	155	134	138	147

4. Copenhagen Business School

	2004	2004	2006	2007	2008	2009
Bachelor HA (it)						
Number of students on bachelor's level	401	322	276	274	243	250
Number of new enrolled on bachelor's level	172	122	116	129	81	96
Number of graduated on bachelor's level	123	107	93	95	55	52
Bachelor HA (im) Information management (new education)						
Number of students on bachelor's level	---	---	61	121	160	180
Number of new enrolled students on bachelor's level	---	---	76	58	59	61
Number of graduated students on bachelor's level	---	---	---	---	---	32
Cand. merc.(it.)						
Number of students on master's level	287	280	255	228	191	197
Number of new enrolled students on master's level	80	48	72	66	52	67
Number of graduated students on master's level	46	74	61	62	59	60

Total for CBS						
Total numbers of students	688	602	592	623	594	627
Total number of graduated students	169	181	154	157	114	144

Copenhagen University College of Engineering	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Information and Communication Technology						
Number of students on bachelor's level	187	181	151	142	109	106
Number of graduated students on bachelor's level	67	53	59	39	36	32
Electronics Computer Engineering						
Number of students on bachelor's level	306	287	293	248	186	132
Number of graduated students on bachelor's level	55	51	40	68	53	58
Total numbers of students	493	468	444	390	295	238
Total number of graduated students	122	104	99	107	89	90

5. Roskilde University

Roskilde University Computer Science	2004	2005	2006	2007	2008	2009
Computer Science						
Number of students on master's and bachelor's level	221	227	195	197	142	114
Number of graduated students on bachelor's level	35	50	28	46	20	24
Number of graduated students on master's level	12	14	23	30	25	20
Informatics						
Number of students on informatics	0	0	0	17	28	44
Number of graduated students on bachelor's level	0	0	0	0	11	17
Number of graduated students on master's level	0	0	0	0	0	1
Total for RUC						
Total numbers of students	221	227	195	214	170	158
Total number of graduated students	47	64	51	76	56	62

6. Aalborg University/Copenhagen: Ballerup Campus

Aalborg University/Copenhagen	2004	2005	2006	2007	2008	2009
Bachelor's in Medialogy						
Number of students on bachelor's level	184	226	269	268	278	284
Number of graduated students on bachelor's level	76	64	27	50	43	31
Master's in Medialogy						
Number of students on master's level	13	25	36	28	51	64
Number of graduated students on master's level			10	10	9	8
Master's in Innovative Communication and Entrepreneurship						
Number of students on master's level		0	0	0	0	1
Number of graduated students on master's level					0	0
Total for Aalborg University Ballerup						
Total numbers of students	197	251	305	296	329	349
Total number of graduated students	76	64	37	60	52	39

7. University of Southern Denmark: Slagelse Campus

University of Southern Denmark: Slagelse Campus	2004	2005	2006	2007	2008	2009
Bachelor's in Economics and Information Technology						
Number of students on bachelor's level	0	0	-0	0	35	33
Number of graduated students on bachelor's level	0	0	0	0	5	28
Total number of students at Univ. of Southern Denmark Slagelse	0	0	0	0	35	33
Total number of graduated students	0	0	0	0	5	28

ICT Education in Scania

1. Lund University: Faculty of Engineering, LTH

Lund University: Faculty of Engineering, LTH	2004	2005	2006	2007	2008	2009
Master's degree (five-year master's) Master´s degree in Computer Science						
Number of students	568	519	476	459	505	541
Number of graduated students	116	93	69	70	62	58
Master´s degree in Electrical Engineering						
Number of students	573	496	386	356	350	395
Number of graduated students	128	134	104	79	63	45
Master's degree in InfoCom						
Number of students	162	154	158	139	134	144
Number of graduated students	0	6	17	16	26	18
Total for master's level (five years)						
Number of students	1,303	1,169	1,020	954	989	1,080
Number of graduated students	244	233	190	165	151	121

International Programme for Master of Science 120 ECTS English Photonics						
Number of students					4	22
Number of graduated students					0	0
System-on-Chip						
Number of students enrolled	47	48	61	83	89	106
Number of graduated students	4	16	21	11	21	39
Wireless Communication						
Number of students				28	56	83
Number of graduated students				0	0	13
Total for Master of Science English 120 ECTS						
Number of students	47	48	61	111	149	211
Number of graduated students	4	16	21	11	21	52
Total for Lund University Faculty of Engineering, LTH						
Total number of students in IT programs	1,350	1,217	1,081	1,065	1,138	1,291
Total number of graduates in IT programs	248	249	211	176	172	173

2. Campus Helsingborg/LTH

Faculty of Engineering/Campus Helsingborg/LTH	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Bachelor's degree						
Bachelor's in Computer Science						
Number of students	78	70	78	74	84	116
Number of graduated students	8	14	5	6	14	8
Bachelor's in Electrical Engineering						
Number of students	50	21	8	4	1	1
Number of graduated students	8	21	11	8	5	1
Bachelor's in Software Engineering						
Number of students	11	7	1	1	0	1
Number of graduated students	0	5	2	0	0	0

Total for bachelor's level						
Number of students	139	98	87	79	85	118
Number of graduated students	16	40	18	14	19	9
Total for Campus Helsinborg/ LTH						
Total number of students in IT programs	139	98	87	79	85	118
Total number of graduated in IT programs	16	40	18	14	19	9

3. Lund University

Lund University	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Department of Informatics						
Bachelor's Program in Design of Information Systems						
Number of students	281	254	238	210	205	227
Number of graduated students	18	20	37	23	33	21
Master's Program in Information Systems, 60 ECTS						
Students on master's level[10]				14	31	32
Number of graduated students	21	29	29	22	17	9
Total for Lund University, Department of Information Systems						
Total number of students in IT programs	281	254	238	224	236	259
Total number of graduated students in IT programs	39	49	66	45	50	30
Department of Computer Science						
Bachelor's Program in Math-Nat. in Computer Science[11]						
Number of students on bachelor's level	142	142	107	95	40	30
Number of graduated students on bachelor's level	1	3	0	1	4	6
Number of graduated students on master's level[12]	18	25	10	8	6	3

10. The students were enrolled on the bachelor level in the period from 2004-2006 and needed another year for a master's degree. From 2007, it was a specific programme.

11. No students were enrolled after 2007.

12. All students are enrolled on the bachelor's level. If you take a fourth year, you get a master's degree.

International Master's Program in Computer Science, 120 ECTS[13]						
Number of students on master's level		15	30	43	39	31
Number of graduated students on master's level				2	4	8
Total for Lund University, Department of Computer Science						
Total number of students in IT programs	142	157	137	138	79	61
Total number of graduated students in IT programs	19	28	10	11	14	17

3. Malmö University

Malmö University	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Faculty: School of Technology						
Department of Computer Science						
Bachelor of Science Program in Software Engineering						
Number of students on bachelor's level	49	24	10	1		
Number of graduated students on bachelor's level	7	6	7	9	3	3
Bachelor of Science Program in Computer Technology						
Number of students on bachelor's level	35	20	8	1		
Number of graduated students on bachelor's level	6	6	8	4	2	1
Bachelor of Science Program in Computer Science and Image Analysis						
Number of students on bachelor's level	12	9				
Number graduated students on bachelor's level	0	1	2	0	1	0

13. No students enrolled after 2007.

Bachelor of Science program with Image Analysis						
Number of students on bachelor's level	1					
Number of graduated students on bachelor's level[14]	4	1	0	1	0	2
Bachelor of Science in Computer Science and Electrical Engineering						
Number of students on bachelor's level	102	77	43	24	4	0
Number of graduated students on bachelor's level	42	26	24	14	14	3
Bachelor of Science Information Architecture						
Number of students on bachelor's level			32	54	83	90
Number of graduated students on bachelor's level			0	0	0	2
Bachelor of Science System Developer						
Number of students on bachelor's level						34
Number of graduated students on bachelor's level						0
Bachelor of Science Business Intelligence - Technology and Management						
Number of students on bachelor's level			37	67	98	97
Number of graduated students on bachelor's level			0	0	0	2
Bachelor of Science in Computer and Telecom Engineering						
Number of students on bachelor's level			11	24	40	67
Number of graduated students on bachelor's level			0	0	0	0

14. The number of graduated students can exceed the number of enrolled students because the students do not have to enroll if he or she just needs a single course to complete the programme.

Bachelor of Science Computer and Telecom - Technology and Management						
Number of students on bachelor's level			48	82	93	98
Number of graduated students on bachelor's level			0	0	0	0
Total for Malmö University School of Technology						
Total number of students in IT programs	199	130	189	253	318	386
Total number of graduated students on IT programs	59	40	41	28	20	13
Faculty of Culture and Society						
Department of Art, Culture and Communication						
	2004	2005	2006	2007	2008	2009
Bachelor's Program in Interaction Design						
Number of students on bachelor's level	114	123	142	118	106	102
Number of graduated students on bachelor's level	18	11	16	11	7	6
Master's Program in Interaction Design 1/						
Number of students on master's level (one-year master's)	11	12	16	12	11	12
Number of graduated students on one-year master's level	19	6	5	3	5	1
Number of students on two-year master's level	6	7	14	11	8	7
Number of graduated students on two-year master's level	0	0	0	0	0	1

Malmö University Department of Art						
Culture and Communication						
Total number of students in IT programs	131	142	172	141	125	121
Total number of graduated students in IT programs	37	17	21	14	12	8

1/ After one year, you receive a master's degree called a Swedish master's degree, and after two years, you receive an international master's degree.

5. Kristianstad University

Kristianstad University	2004	2005	2006	2007	2008	2009
Department of Computer Science						
Bachelor of Science Program in Computer Software Development						
Number of students on bachelor's level	110	115	110	159	191	238
Number of graduated students on bachelor's level	9	10	11	8	16	7
Bachelor of Science Program in Computer Science and Engineering						
Number of students on bachelor's level	0	0	0	0	4	14
Number of graduated students on bachelor's level	0	0	0	0	0	0
Bachelor of Science Program in Electronics and Computer Engineering						
Number of students on bachelor's level	77	51	26	14	2	0
Number of graduated students on bachelor's level	23	12	9	5	1	0

Bachelor of Science: Interactive Sound Design Program						
Number of students on bachelor's level	0	0	19	35	40	37
Number of graduated students on bachelor's level	0	0	0	0	0	0
Total for bachelor's level						
Number of students on bachelor's level	187	166	155	208	237	289
Number of graduated students on bachelor's level	32	22	20	13	17	7
Data System Manager, 120 ECTS						
Number of students on diploma level	0	26	40	59	60	41
Number of graduated students in Diploma in System Management	0	0	0	2	3	5
IT Technician, with a Specialization in System Management, 120 ECTS						
Number of students in diploma level	0	0	0	0	0	38
Number of graduated students in Diploma in System Management	0	0	0	0	0	0
Total for diploma level						
Number of students on diploma level	0	26	40	59	60	79
Number of graduated students on diploma level	0	0	0	2	3	5
Master's Program with a Specialization in Embedded Systems, 60 ECTS[15]						
Number of students on master's level	23	12	2	32	34	37
Number of graduated students on master's level	4	4	4	3	14	29

15. You can be enrolled in this programme after finishing a bachelor's level ICT programme.

Master's Program in Digital Communication Design, 60 ECTS[16]						
Number of students on master's level	0	25	46	26	3	0
Number of graduated students on master's level	0	0	0	20	20	4
Total for master's level						
Number of students on master's level	23	37	48	58	37	37
Number of graduated students on master's level	4	4	4	23	34	33
Total for Kristianstad University Department of Computer Science						
Total number of students in IT programs	210	229	243	325	334	405
Total number of graduated students in IT programs	36	26	24	38	54	45

16. You can be enrolled in this programme after finishing a bachelor's level ICT programme.

Appendix IV

Number of ICT students on Zealand by Business Academy Education programs

New enrolled students	2001	2002	2003	2004	2005	2006	2007	2008
Computer Science, KVU	1,030	747	498	334	389	277	365	482
IT and Electronics, KVU	78	62	54	38	48	73	87	101
Multimedia Design, KVU	841	577	548	442	479	551	550	619
Total	1, 949	1,386	1,100	814	916	901	1,002	1,202
Number of graduated students								
Computer Science, KVU	535	687	597	454	261	206	129	87
IT and Electronics, KVU	NA	32	44	40	38	18	25	39
Multimedia Design, KVU	NA	470	660	357	290	257	273	277
Total		1,189	1,201	851	589	481	427	403
Number of enrolled students								
Computer Science, KVU	2,288	1,790	1,264	822	745	568	617	757
IT and Electronics, KVU	109	117	104	88	79	103	146	155
Multimedia Design, KVU	1,352	1,193	985	813	800	897	869	1,012
Total	3,749	3,100	2,353	1,723	1,624	1,568	1,632	1,924

Appendix V

ICT products and service must primarily be intended to fulfill or enable the function of information processing and communication by electronic means, including transmission and display.

1. The narrow definition is ICT specialists, that is, those individuals who have the ability to develop, operate and maintain ICT systems and for whom ICT is the main part of their job.

2. The broad definition includes ICT specialists as advanced ICT users for whom ICT is a tool for their job. Advanced users are competent users of advanced, and often sector-specific, software tools.

Based on OECD: Guide for Measuring the Information Society (OECD, 2005)

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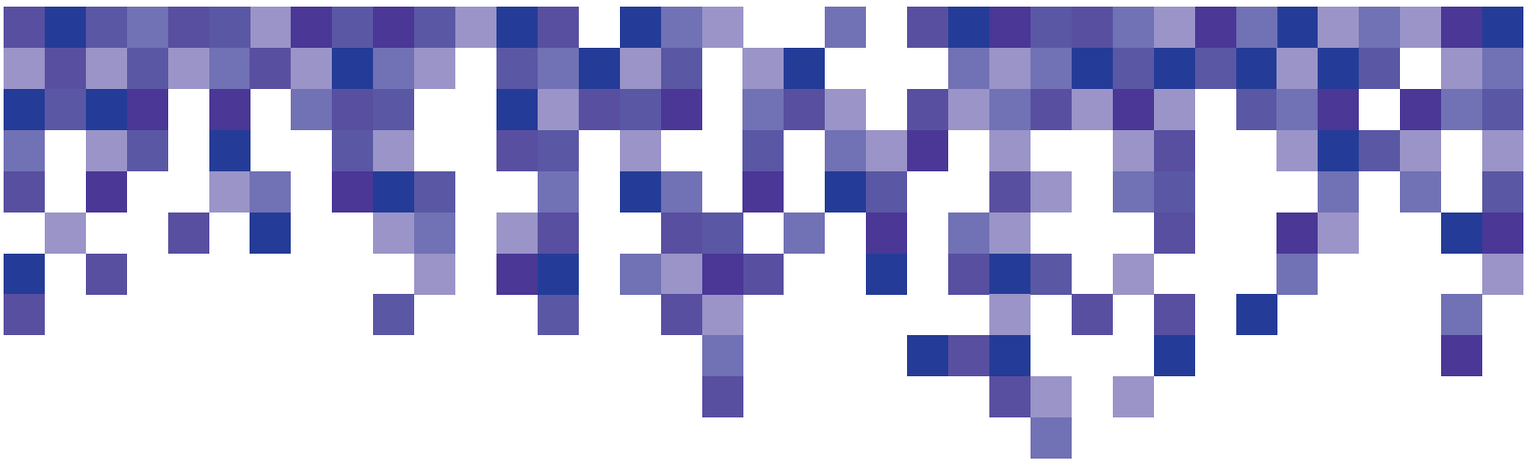

Innovation, R&D and education in the ICT sector in the Øresund Region

ISBN: 978-91-974500-1-0

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

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ÖRESUND – KATTEGAT – SKAGERRAK