The Danish Centre for Studies in Research and Research Policy
University of Aarhus Finlandsgade 4 DK-8200 Århus N.
Phone (+45) 8942 2394 Fax (+45) 8942 2399 www.cfa.au.dk

Mapping R&D in information and communication technologies – methodology and results of the Danish ICT R&D survey 2003

Carter Bloch* and Peter S. Mortensen$^{\tau}$

May 31, 2006

Working paper 2006/5
The Danish Centre for Studies in
Research and research Policy

ISBN: 87-91527-28-7

Abstract
While the central importance of information and communications technologies (ICT) for innovation and growth has been very widely stressed, there have been almost no attempts to measure ICT R&D activities. This paper discusses a specialized survey of R&D within ICT that has been conducted in Denmark. The Danish ICT R&D survey covers ICT R&D activities in both the public and private sector, thereby allowing a matching of R&D in firms and public research institutions, with a number of insights for policy. The survey offers valuable input for policy and provides a methodology that can readily be applied to other areas.

Keywords: Information and communication technology, R&D

* Corresponding author. Tel.: (+45) 8942 2398, E-mail: carter.bloch@cfa.au.dk.
$^{\tau}$ Tel. : (+45) 8942 2397, E-mail: psm@cfa.au.dk.

1. Introduction

Information and communication technology (ICT) has become a key technology in the last decade. Many studies have documented the impact of ICT on productivity[1], with a large potential to contribute to growth and productivity gains in the future. The internet, mobile telephony and broadband networks are now widespread, and computers and computer networks are used for broad range of economic purposes. Furthermore, ICTs are embedded into a diverse and increasing number of other products and services.

The importance of ICT creates a need for greater knowledge on its characteristics and development. There is now extensive data on ICT usage both in firms and households[2]. However, there exists little specialized data on R&D activity within ICTs. Only aggregated data is available on levels of R&D in the ICT sector (manufacturing and services)[3]. This stands in stark contrast to the now widespread collection of data on for example biotechnology activities (van Beuzenkom, 2004).

R&D is a central element in the development and application of ICTs in a number of ways. First, ICT industries are under constant change. The development of new technologies and new products based on recent advances is vital for the growth and international competitiveness of ICT industries.

However, the applications of ICTs go far beyond ICT sectors. A wide range of other sectors are increasingly integrating ICTs into their products. This process is seldom simple and often requires substantial R&D by the firms themselves in adapting technologies for integration in their products.

Finally, R&D within ICTs may have substantial benefits that reach beyond those firms that are actually engaged in R&D. Globalisation has significantly increased the flow of knowledge across large distances. However, a solid national R&D base may be vital for the general adoption and use of ICTs within the country.

[1] See e.g. OECD (2003a, 2004, 2005a) and the references within.
[2] Such as Eurostat's harmonized EU survey of ICT-usage in firms and households. See Eurostat (2006).
[3] See e.g. the OECD Key ICT Indicators 2005.

A recent survey in Denmark, conducted by the Danish Centre for Studies in Research and Research Policy (CFA) on behalf of the Danish Ministry of Science, Technology and Innovation, makes a first attempt at covering R&D activities within ICTs. The ICT R&D Survey 2003 seeks to collect data on ICT R&D throughout the economy. The survey thus includes firms both within ICT-related industries and in a variety of other industries, and public research institutions (PRI) from a broad range of academic fields.

The main purpose of the ICT R&D survey is to provide input to policy discussions related to the Danish government's recent IT strategy[4].The goals of the survey are thus to obtain a detailed mapping of ICT R&D in the private and public sectors and, importantly, to examine interaction between firms and PRIs.

This paper presents the results of the ICT R&D 2003 Survey. Among the topics covered in the survey are: a detailed classification of types of ICT R&D, patterns of cooperation, barriers to ICT R&D, and focus areas for future R&D. To our knowledge, this survey is the first of its kind to cover R&D in ICTs. An additional novel aspect is the coverage of R&D activities in PRIs. A high degree of correspondence is maintained between questionnaires for firms and PRIs, allowing us to match R&D activities in the public and private sectors.

The results provide a number of insights on R&D activity within ICTs. Furthermore, the methodology behind the survey can also be useful in an international context. It is our view that there is substantial need for data from specialized surveys within ICTs and also in a number of other areas, and this need is likely to increase in the future.

The next section discusses the main conceptual issues that influenced the design of the survey, and outlines its structure. The paper then presents the main results of the survey. The final section discusses policy implications and concludes. The statistical methodology used in the survey is described in the appendix.

[4] Danish Ministry for Science, Technology and Innovation (2002a,b).

2. Conceptual issues and methodology

As mentioned above, the overall objective of the Danish ICT R&D survey is to map ICT R&D in business enterprise and public sectors and the linkages between them for use in IT policymaking. Among the issues that guided the design of the survey were: where does ICT R&D take place? What types of research are conducted within ICT, and in what areas? What types of linkages are there between actors? Which factors hinder ICT R&D and which areas are seen as most important for future research? And to what degree do PRIs commercialize their ICT research?

To assist in the design of the survey, a reference group was formed consisting of experts within ICT from business and the public sector and representatives from CFA and the Ministry of Science, Technology and Innovation. The main tasks of this group were to form a definition of ICT for use in the surveys and to develop a classification for types of ICT R&D.

In defining information and communication technology, a fairly broad formulation was chosen in order to capture all ICT-related R&D[5]:

> *ICT comprises information technologies, communication technologies and related electronics. The area of ICTs consists of the group of technologies for the storage, processing, transmission and interpretation of information, also including the use, understanding and impact of these technologies.*
>
> *ICT R&D includes both the development of technologies within ICT, and R&D that concerns the application, significance, comprehension and consequences of ICTs. ICT R&D does not include R&D where ICTs are solely used as a support activity or tool; ICT must be the object of the R&D activity.*

[5] For comparison, the guiding principles for the OECD's definition of the ICT sector:
"The list of ICT sector activities was decided on the basis of the following set of principles.
For manufacturing industries, the products of a candidate industry: must be intended to fulfill the function of information processing and communication including transmission and display, OR must use electronic processing to detect, measure and/or record physical phenomena or to control a physical process.
For services industries, the products of a candidate industry: must be intended to enable the function of information processing and communication by electronic means." (OECD, 2005b, p. 30)

A central element in the survey methodology was the classification of types of ICT R&D. ICT R&D was classified along two dimensions, in terms of its use and in terms of research areas. Three main groups were identified according to its use:

- *Hardware*, including hardware used for communication and used for data processing
- *Stand-alone software*, both standardized and customized software
- *Integrated software*, which involve software that is embedded in other products

In all 12 research areas were identified by the reference group for ICT R&D:

- *Database and software tools*
- *Data storage and network management*
- *Instruments*
- *Security systems*
- *Business systems*
- *Process control*
- *Communication systems*
- *Microelectronics*
- *Image technology*
- *Language technology*
- *Usability*
- *Games*

In addition, questionnaires for private and public sectors were made as comparable as possible, in order to aid in comparison. Furthermore, all firms and PRIs were also included in the general R&D surveys, in order to allow a link with standard R&D data. The survey was originally intended as an ad hoc survey, but has since been planned to be held every two years.

For the purpose of matching public and private ICT R&D, we are interested in which areas firms and PRIs conduct ICT R&D within and, additionally, in collaborative relationships, both between firms and with PRIs. Knowledge transfers between industry and science can run through a number of channels (Polt et al., 2001; OECD, 2003b). One channel is

research personnel and students that bring knowledge to their new workplaces. Another is publication, and a third is through collaborative research projects. Finally, PRIs can transfer knowledge to businesses through commercialization of the research results via patents, licenses or spin off firms. The ICT R&D survey focuses on two of these channels, collaborative relationships and commercialization of research.

Industry-science relations also depend on the type of technology and its maturity, where PRIs may take one of three roles: as suppliers of the newest, state of art technologies, as equal partners in the application of more developed technologies, and as consultants concerning established technologies. Data on collaborative relationships and types of partners may provide us with some information on types of technology for Industry-Science relations.

In determining the samples for the private and public sectors, it is important to ensure that non-ICT sectors are well represented. Here use is made of data from the general R&D survey on firms and PRIs research areas. Both the private and public R&D surveys in Denmark contain a question on research areas, where respondents estimate the share of their R&D within each area. This data combined with information on industrial classifications or academic fields were used to form a population of firms and PRIs that potentially have ICT-related R&D. The question on research areas can be useful in identifying firms in other areas, for example biotechnology. The statistical methodology of the ICT R&D survey is described in greater detail in the appendix.

3. Survey results

In all 1.09 billion € was spent on R&D within ICT in Denmark in 2003. That amounts to 22 percent of all R&D expenditures in Denmark in 2003. One billion of this was conducted in the business enterprise sector and around 90 million by public research institutions (PRI). ICT's share of R&D in the business sector is correspondingly much higher than in the public sector, 29 percent compared to 6 percent. This is somewhat surprising given the high priority placed on ICT in Danish policy strategies.

An interesting result concerning overall R&D figures within ICT is that almost one third of business ICT R&D is conducted in non-ICT industries. Thus, far from the simple adoption

of existing technologies, many firms from other industries are active in the development and application of ICTs in their products and business processes.

Table 1 shows a breakdown of business ICT R&D by industry[6]. In all, around 400 firms conducted ICT R&D in Denmark in 2003. This includes firms from wide range of industries, also in low-tech industries within manufacturing and services. 10 percent of firms are from non-ICT manufacturing industries and 12 percent from non-ICT services. This gives an indication of the pervasiveness of ICT in terms of its development and application.

A very high share of ICT R&D is in services, around three quarters. This is very atypical in international comparison, where R&D in the ICT sector for most OECD countries is predominantly in manufacturing[7].

Table 1 Business ICT R&D by industry

	Expenditures		Firms	
	R&D (MN €)	R&D (%)	% total firms	Share with under 50 employees
Manufacturing				
ICT				
Radio, TV and communication equipment	87	9%	9%	45%
Instruments for measuring and testing	64	6%	4%	33%
Non-ICT				
Materials, metals	29	3%	3%	43%
Machinery	22	2%	4%	0%
Medical instruments	20	2%	3%	23%
Services				
ICT				
Wholesale of computers and equipment	24	2%	1%	0%
Telecommunications	83	8%	2%	0%
Software consultancy and development	410	41%	53%	84%
Computer and related activities (minus software consultancy)	11	1%	8%	84%
Non-ICT				
Financial intermediation	209	21%	2%	0%
Research and development	25	3%	2%	0%
Legal, accounting and auditing activities	5	1%	6%	86%
Architectural and engineering activities and related technical consultancy	14	1%	2%	0%
Total	**1003**	**100%**	**100%**	**63%**

[6] ICT industries follow the OECD's definition of the ICT sector. See OECD (2005b).
[7] See OECD Key ICT Indicators 2005.

Over 40% of R&D expenditures are in software consultancy and development, with over half of ICT R&D active firms. Software consultancy and development thus comprise the most significant industry for Danish ICT activity. This industry also has a very high share of smaller firms. Over 80 percent of firms in this industry have less than 50 employees. Second largest in terms of R&D expenditures is financial intermediation, where firms in banking and insurance account for over 20 percent of ICT R&D expenditures in 2003.

Overall, about two thirds of all firms with ICT R&D have less than 50 employees. This may be important for policy considerations, in order to ensure that policy measures address the needs of smaller firms.

80 percent of ICT R&D was spent on development activities and 20 percent on research, 7 percent of which was basic research. The share of expenditures within research was somewhat higher for firms in the ICT sector compared to those in other industries, 23 percent compared to 14 percent.

The public sector survey covers the Higher education (HES), Government (GOV) and Private non-profit (PNP) sectors. However, almost all public ICT R&D was conducted in the Higher education sector[8]. In all 48 academic departments or institutes reported that they conducted research in ICTs. These institutes are quite diverse and are found in five out of six main fields of science: Natural sciences, Engineering and Technology, Medical Sciences, Social Sciences and Humanities[9]. Table 2 shows the main R&D figures by academic field.

Table 2 Public sector ICT R&D by field of science

	Expenditures		Type of R&D			Institutes
	R&D (MN €)	R&D (%)	Basic research (%)	Applied research (%)	Development (%)	% total
Natural Sciences	43	47%	46%	40%	14%	33%
Engineering and technology	29	32%	20%	65%	15%	25%
Social Sciences	5	6%	20%	64%	15%	15%
Humanities	14	16%	37%	39%	24%	27%
Total	**91**	**100%**	**35%**	**49%**	**16%**	**100%**

[8] In all two institutes within GOV and none from PNP reported R&D within ICT.
[9] Due to the small number of institutes within Medical Sciences with ICT R&D, Medical Sciences is combined with Natural Sciences for all relevant tables and calculations in this paper.

The largest share of public ICT R&D expenditures is in Natural Sciences, followed by Engineering and Technology. There are a roughly equal number of institutes in Natural sciences, Engineering and Technology, and Humanities.

The highest share of basic research is in Natural Sciences, which is predominantly conducted in Computer Science departments. Institutes within Engineering and Technology cover a number of applied areas, such as electronics, mechanics, energy technology and communication technology. Not surprisingly, a much higher share of R&D for these institutes is devoted to applied research. ICT R&D at institutes within Humanities is relatively evenly divided between basic and applied research and development. Among the areas within Humanities are information science, media and communication, and language technology.

In comparison with the business sector, the relation of research to development expenditures is the opposite for the public sector, with over 80 percent of public ICT R&D going to research compared to 20 percent for firms.

Two sets of questions are utilized to classify ICT R&D, one in terms of usage groups (i.e. hardware, stand-alone or integrated software) and the other in terms of ICT research areas. There are two main objectives for these questions. The first is to be able to identify the strengths and weaknesses in Danish ICT R&D. The second is to facilitate the mapping of private sector ICT R&D with that conducted at public research institutions.

Table 3 shows the distribution of ICT R&D by main usage groups for private and public sectors. Overall, the distribution of R&D expenditures by usage groups is very much similar for the private and public sectors. In both sectors, around half of expenditures are devoted to stand-alone software, 35 percent to software integrated into other products, and 15 percent to hardware.

In the private sector, manufacturing has a relatively large share of expenditures within hardware, while over 75 percent of expenditure for ICT services are within stand-alone software products. In contrast, over two thirds of expenditures for non-ICT services are devoted to software integrated in other products.

Table 3 ICT R&D by main usage groups

Business enterprise sector	Hardware	Standard Software	Integrated Software
ICT manufacturing	49.8%	9.9%	40.3%
ICT services	5.8%	76.7%	17.5%
Non-ICT manufacturing	34.4%	49.1%	16.4%
Non-ICT services	6.1%	25.2%	68.7%
Total	14.4%	51.4%	34.2%

Public sector	Hardware	Standard Software	Integrated Software
Natural Sciences	9.7%	58.6%	31.6%
Engineering and technology	27.2%	25.6%	47.2%
Social Sciences and Humanities	12.1%	57.7%	30.2%
Total	15.8%	47.9%	36.3%

Examining the public sector, both Natural sciences and Social Sciences/Humanities have around 90 percent of expenditures in software, mainly stand-alone software. Institutes in Engineering and Technology in contrast have much greater shares of ICT R&D in hardware and integrated software.

A rough, general pattern is that manufacturing firms are best matched with applied institutes within Engineering and Technology, while services firms may potentially benefit most from research at institutes within the other fields.

Table 4 shows ICT R&D distributed according to research area. ICT R&D in the private sector is focused on three areas: Business Systems, Communication Systems and Database/Software Tools. Substantially less R&D is devoted to the other areas. Public sector ICT R&D is in contrast much more evenly spread over the 12 areas. The three largest areas for the public sector are: Database/Software Tools, Communication Systems and Usability.

For manufacturing, R&D in ICT industries is concentrated in Communication Systems and to a lesser extent in Instruments, whereas the largest area for non-ICT industries is Database/Software Tools. Note also that while Business Systems is the largest area overall in the private sector, R&D in this area is primarily confined to the service sector.

Table 4 ICT R&D by research area

	Database and Software Tools	Data Storage/ Network Mgmt.	Instru-ments	Security Systems	Business Systems	Process Control	Communi-cation Systems	Micro-electronics	Image Technology	Language Technology	Usability	Games	Other
ICT manufacturing	2%	3%	12%	1%	0%	4%	33%	3%	5%	·	2%	0%	34%
ICT services	12%	3%	3%	3%	16%	1%	26%	3%	3%	·	4%	2%	23%
Non-ICT manufacturing	23%	0%	8%	0%	9%	4%	12%	4%	1%	·	2%	0%	38%
Non-ICT services	4%	2%	2%	6%	44%	7%	1%	1%	0%	·	2%	0%	31%
Total	**9%**	**3%**	**5%**	**3%**	**21%**	**3%**	**20%**	**2%**	**2%**	·	**3%**	**1%**	28%

	Database and Software Tools	Data Storage/ Network Mgmt.	Instru-ments	Security Systems	Business Systems	Process Control	Communi-cation Systems	Micro-electronics	Image Technology	Language Technology	Usability	Games	Other
Natural Sciences	19%	3%	5%	5%	6%	5%	6%	0%	9%	4%	6%	5%	26%
Engineering and Technology	10%	4%	12%	4%	2%	11%	15%	8%	5%	0%	5%	4%	18%
Social Sciences and Humanities	13%	1%	2%	1%	2%	1%	9%	0%	5%	18%	16%	7%	25%
Total	**15%**	**3%**	**7%**	**4%**	**4%**	**6%**	**10%**	**3%**	**7%**	**6%**	**8%**	**5%**	23%

Note: The research area 'Language Technology' was not included in the private sector survey.

The pattern for the public sector is very much different. Little research is conducted in Business Systems, in great contrast to the private sector. A larger share is devoted to Communication Systems, with the exception of institutions in Natural Sciences. The main area in Natural Sciences is Database/Software Tools, while expenditures in Engineering and Technology are concentrated in Communication Systems, Instruments, Process Control and Database/Software Tools. Social Sciences and Humanities also have a sizable share in Database/Software Tools, along with Usability and Language Technology.

Around a quarter of the expenditures were either classified as 'Other' or not specified. In particular in the business sector there was fairly high item non-response on this question, indicating the need for further work in future surveys.

One interpretation of these results is that there may be a potentially large mismatch between private and public sector R&D in ICTs. A primary focus area of many firms, Business Systems, receives little attention in the public sector. This may hinder interaction between the two sectors.

In order to map ICT R&D in the private and public sectors, it is important to gain information on collaborative arrangements for firms and PRI's. This allows us to examine where cooperation and knowledge exchange are greatest and which types of partners are most frequently used. Firms and PRIs were thus asked in the survey whether they had cooperated with others on their R&D within ICT both in terms of type of partner and whether in Denmark or abroad. Tables 5 and 6 show the results for enterprises and PRIs, respectively.

Examining Table 5, it can be seen that among firms in ICT industries, the percentage with cooperation with other firms in Denmark is relatively low. For ICT manufacturing firms, this appears to reflect a greater reliance on other partners, particularly firms abroad and PRIs. ICT service firms, however, do not have higher rates of cooperation with other partners such as PRIs. The low rates seem instead to reflect the large share of small ICT service firms, which may have a lesser capacity to enter into collaborative relationships with other actors. This is also borne out by the data: small firms in ICT service have generally less cooperation.

Table 5 Firms' R&D cooperation within ICT by sector and type of partner

All firms	Firms, DK	Firms, abroad	Firms total	GTS institutes	University, DK	University, abroad	Universities total	Public sector total*	Any cooperation
ICT manufacturing	48%	60%	75%	49%	60%	15%	60%	72%	90%
ICT services	47%	36%	54%	3%	30%	18%	34%	45%	74%
Non-ICT manufacturing	86%	35%	92%	42%	58%	20%	61%	70%	97%
Non-ICT services	74%	19%	81%	19%	40%	22%	41%	49%	89%
All firms	**54%**	**37%**	**64%**	**15%**	**38%**	**19%**	**41%**	**51%**	**81%**
Under 50 employees									
ICT services	46%	29%	52%	0%	26%	18%	26%	40%	74%
ICT manufacturing	53%	46%	73%	61%	73%	10%	73%	80%	90%
Total under 50 employees	**47%**	**31%**	**54%**	**7%**	**32%**	**17%**	**32%**	**44%**	**76%**
At least 50 employees									
ICT services	72%	51%	18%	14%	41%	21%	2%	80%	60%
ICT manufacturing	56%	58%	22%	41%	57%	16%	0%	83%	57%
Total 50 employees or greater	**66%**	**53%**	**19%**	**24%**	**47%**	**19%**	**1%**	**81%**	**59%**

*Public sector total also includes cooperation with GTS institutes, which are technically private independent organizations.

Table 6 PRIs' R&D cooperation within ICT by field and type of partner

	Firms, DK	Firms, abroad	Firms total	GTS institutes	University, DK	University, abroad	Universities total	Public sector total*	Any cooperation
Natural Sciences	88%	50%	94%	31%	88%	75%	94%	94%	94%
Engineering and technology	100%	42%	100%	50%	83%	100%	100%	100%	100%
Social Sciences and Humanities	75%	30%	80%	25%	90%	70%	95%	95%	95%
Total	**85%**	**40%**	**90%**	**33%**	**88%**	**79%**	**96%**	**96%**	**96%**

*Public sector total also includes cooperation with GTS institutes, which are technically private independent organizations.

Note in contrast that small firms in ICT manufacturing do not have lower rates of cooperation. In fact, percentages with cooperation are actually higher for some types of partners.

One type of partner that is specific to Denmark are the GTS technology institutes (Godkendte Teknologiske Serviceinstitutter), which specialize in providing consulting, testing and certification for firms. These institutes seem to provide an important support for manufacturing firms, perhaps less in developing new technologies but rather in terms of aiding with R&D related to the application of existing ICTs for new uses.

Table 6 shows the results for PRIs. Almost all institutes have had cooperation, both with firms and with other PRIs. In addition, 40 % had cooperation with firms abroad and 90 % with international universities. This indicates a fairly strong international orientation for public research within ICTs.

PRIs were also asked whether they had commercialized their ICT research results over the period 2001 to 2003, such as through patenting, licensing or spin off firms. A fairly large share of PRIs actively commercialized their research, particularly those in Natural Sciences and Engineering and Technology. Among institutions in these fields of science, around 25 % had applied for patents for 2001-2003, over a third had sold licenses and over 40 % had established spin-off firms based on their ICT research.

Table 7 Commercialization of public research within ICT

	Patent application	Sold license	Spin off firms	Other	Commercial results in all
Natural Sciences	19%	31%	44%	13%	50%
Engineering and Technology	25%	42%	42%	33%	67%
Social Sciences and Humanities	0%	5%	20%	15%	35%
Total	**13%**	**23%**	**33%**	**19%**	**48%**

All firms in the survey (both those with and without ICT R&D) were asked to rate the importance of a number of hindering factors for their R&D activity within ICTs. Tables 8 and 9 show the percentages of firms and PRIs that cite the listed barriers as important or very important.

Table 8 Factors hampering ICT R&D, business sector. Percent for which barrier is important or very important.

	Economic resources	Human resources	Other firms as collaborative partners	Contacts with public research	Tax rules, regulations
ICT manufacturing	23%	34%	9%	19%	12%
ICT services	32%	20%	0%	5%	25%
Non-ICT manufacturing	23%	33%	3%	6%	12%
Non-ICT services	68%	28%	0%	4%	11%
Total	**34%**	**22%**	**1%**	**7%**	**20%**

Overall for enterprises, the greatest barrier was lack of economic resources, followed by lack of qualified personnel and tax barriers. However, manufacturing firms cite human resources as a greater barrier than economic resources.

A lack of contact with public research was not cited by many firms as an important barrier, with the exception of ICT manufacturing where 20 % cited it as a significant hindering factor. Tax rules were given high importance by 25 % of firms in ICT service, which is much higher than in other industries.

Table 9 Factors hampering ICT R&D, public sector. Percent for which barrier is important or very important.

	Internal funding	External funding	Funding for ICT equipment	Human resources	Recruiting young researchers
Natural Sciences	100%	66%	31%	75%	19%
Engineering and Technology	92%	67%	33%	67%	17%
Social sciences and Humanities	65%	55%	35%	50%	30%
Total	**83%**	**59%**	**33%**	**62%**	**22%**

	Other PRI's as collaborative partners	Firms as collaborative partners	Patent legislation	Legislation for start-up businesses
Natural Sciences	0%	31%	6%	6%
Engineering and Technology	0%	0%	25%	0%
Social sciences and Humanities	5%	15%	5%	10%
Total	**2%**	**16%**	**11%**	**6%**

Table 9 shows the results for PRIs. A large majority cited both lack of funding and qualified personnel as important hindrances to their ICT research. Basic funding was given much greater importance than external funds.

While none of the institutions in Engineering and Technology cited a lack of business partners as an important barrier for their ICT research, nearly one third of institutions in Natural Sciences named this as an important hindering factor.

Only Engineering and Technology cited patent legislation as a great hindrance, though this may be because patents are a more important activity for their research. Problems in recruiting young researchers were greatest for Social Sciences and Humanities.

Firms and PRI's were also asked what, in their view, are the most important focus areas for future ICT research. Responses varied greatly, but many of the focus areas can be loosely placed in one of eight groups.

Table 10 Focus areas for future R&D within ICT

Focus area	Percent of responses
Pervasive Computing (Interfaces, Human-Computer Interaction (HCI), software embedded in other products, intelligent systems)	18 %
Mobile Computing (wireless technologies, both for application in existing products and the development of new products)	6 %
Communication Systems (information search and processing, networks)	12 %
Business Systems (Enterprise Resource Planning (ERP))	6 %
Knowledge Exchange (Improving the use and spreading of knowledge)	11 %
Usability, Learning and Language Technology (user aspects of ICTs)	8 %
Standards and Platforms (standard definitions, infrastructures for data and technologies)	4 %
Health Sector (applications of ICT in the health sector, such as bioinformatics and medical nanotechnology)	10 %
Other	25 %

18 percent of responses[10] can be placed within Pervasive Computing. Pervasive Computing involves embedding ICTs into objects or products, allowing them to communicate with people or other objects. 11 percent of responses listed Knowledge Exchange as an important focus area for future ICT R&D, while 4 percent named Standards and Platforms. Two groups were cited only by PRI's, the first being aspects related to human interaction with computers, such as Usability, E-learning and Language Technology, and the second concerning the development of new ICT-based applications within the health sector

4. Discussion and policy implications

The Danish ICT R&D Survey provides a first example of a specialized survey covering R&D activities within information and communication technologies. An additional novelty is the coverage of both the private and the public sectors, providing a number of opportunities for mapping industry-science relations. The survey is useful as an example of specialized R&D surveys and in providing insights for policy. The following sums up the main results of the survey and their implications for policy.

In all, around 1.1 billion euros were spent on R&D within ICT in Denmark in 2003. About 30 percent of Danish business R&D is within ICT. This reflects a strong ICT R&D base within services, given that three quarters of business ICT R&D is within services. ICT R&D within manufacturing, in contrast, is much smaller.

By far the largest industry in terms of ICT R&D (and in number of firms) is software development and consulting, with 40 percent of R&D expenditures and over half of firms. Over 80 percent of R&D firms in this industry have 50 employees or less.

In both the private and public sectors, around 85 percent of ICT R&D is within software and only 15 percent within hardware. However, the share spent on hardware is higher for manufacturing industries and for PRI in Engineering and Technology.

In terms of research areas, business sector ICT R&D is concentrated in a few areas (Business Systems, Communication Systems, Database/Software Tools) while public

[10] Note that many firms and PRI's had more than one response.

sector ICT R&D is more evenly distributed. In examining how well public and private ICT R&D match up, Database/Software Tools and Communication Systems can also be considered focus areas in the public sector. However, very little R&D is conducted in Business Systems. This mismatch, in which Business Systems is a key application area for business but not prioritized by PRIs, may mean that potential synergies can be lost for industry-science relations. It may thus be worthwhile to examine this issue in greater detail.

There are a number of insights concerning R&D cooperation within ICTs. First, the share of cooperative arrangements is lower for small firms, both with other firms and with PRIs. This may be important for policy, particularly given that around two thirds of firms with ICT R&D in Denmark have less than 50 employees. Second, a high share of manufacturing firms engaged in R&D cooperation with GTS Technology Institutes. It would appear that these institutes perform an important function in aiding ICT R&D activities for manufacturing firms, one that could potentially be strengthened in the future and expanded towards service firms.

Appendix. Statistical methodology of the ICT R&D survey

The population for the business sector survey was chosen using three sources: industrial classification, and information on research areas and product groups, taken from the general R&D survey. Firms within ICT related categories from at least one of the three sources were included in the population.

The total population for the business sector survey was 2650 enterprises. Due to resource constraints, the target population was restricted to those firms in the total population that had reported R&D in at least one R&D survey over the period 2000 – 2002 or were included in the 2003 R&D sample. This resulted in a target population of 700 enterprises. Given sampling frequencies for the R&D survey (100% for 100+ employees, 50% for 50-99, 33.3% for 25-49, 25% for 10-24 and 10% for 2-9), the target population was thought to include most firms with ICT R&D in Denmark. The same sampling percentages were used for the ICT R&D survey, yielding a final sample of 288 firms.

The response rate was 61 percent. An additional 69 firms were estimated using cold deck methods for 2001 or 2003 R&D data. This gave in all 243 responses, 149 of which had ICT R&D. Item non-responses were imputed where possible. Finally, the results were weighted to reflect the full target population of 700 firms.

PRIs were chosen on the basis of three criteria from the general public sector R&D survey 2003: ICT-related fields of science or research areas, and a minimum of three full-time equivalents (FTE) in ICT-related areas. The target population consisted of 63 units. The public sector survey is a census survey, so all 63 were included in the ICT sample. 48 PRIs reported that they had ICT R&D in 2003, and the remaining 15 reported that they only used ICTs as a support tool or activity.

References

Danish Ministry of Science, Technology and Innovation, 2002a, Oplæg til dansk it-forskningsstrategi (in Danish).

Danish Ministry of Science, Technology and Innovation, 2002b, IT Research and Development in Denmark.

Eurostat, 2006, Methodology Manual for Statistics on the Information Society, Eurostat, Luxembourg.

OECD, 2002, *Proposed Standard Practice for Surveys for Research and Experimental Development, Frascati Manual 2002*, OECD, Paris.

OECD, 2003a, ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms, OECD, Paris.

OECD, 2003b, *Turning Science into Business: Patenting and Licenses at Public Research Organisations*, OECD, Paris.

Polt, W., H. Gassler, A. Schibany, C. Rammer, N. Valentinelli og D. Schartinger (2001), *Benchmarking Industry-Science Relations – The Role of Framework Conditions*.

OECD, 2004, The Economic Impact of ICT: Measurement, Evidence and Implications, OECD, Paris.

OECD, 2005a, OECD Information Technology Outlook 2004, OECD, Paris.

OECD, 2005b, Guide to Measuring the Information Society, OECD, Paris.

van Beuzekom, B., 2004, Biotechnology Statistics in OECD Member Countries: An Inventory, OECD, Paris.