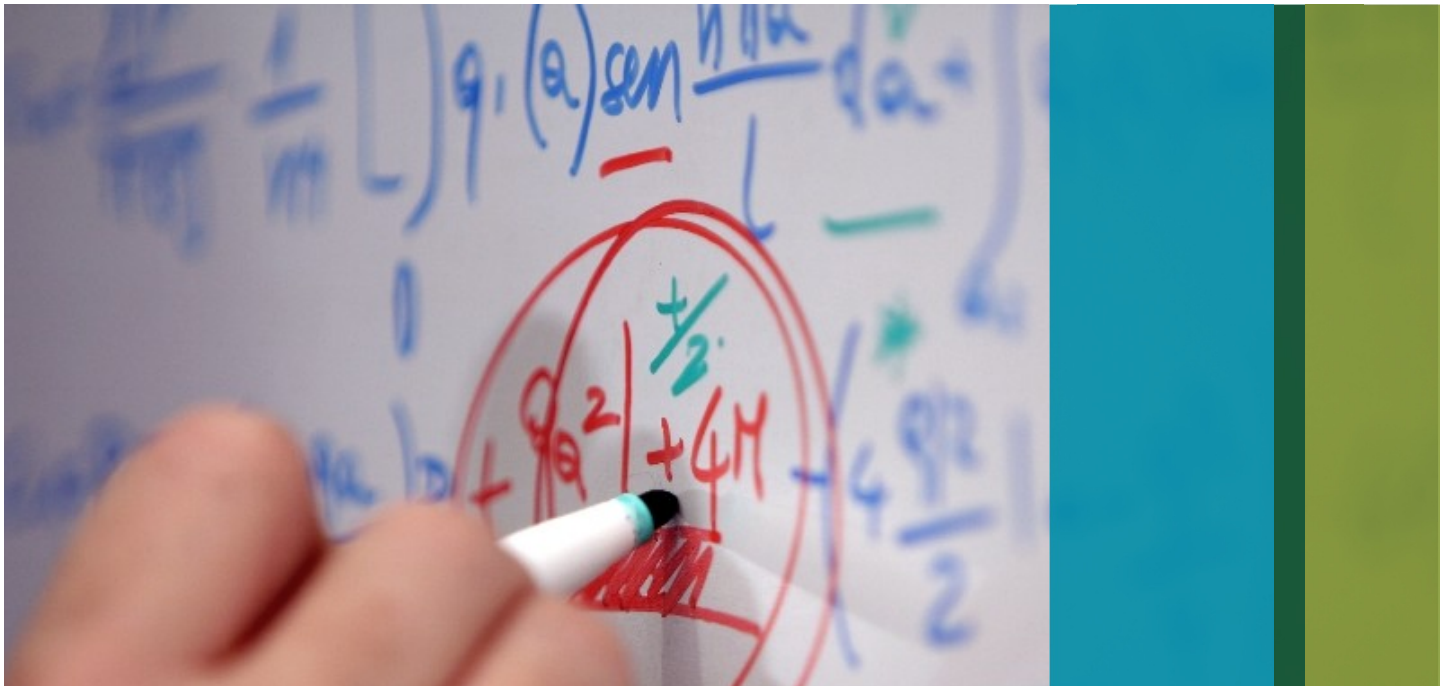

4 May 2013

Core competences in Danish private sector R&D and their economic importance

Summary report from a series of analyses commissioned by the Danish Agency for Science, Technology and Innovation

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Contents

1 Introduction and summary of findings

This report presents the key results from a mapping of core competences in Danish private sector R&D commissioned by the Danish Agency of Science, Technology and Innovation.

The aim of the mapping was to undertake a systematic and comprehensive identification of research areas in which Danish firms make a significant contribution to the international research front. Furthermore, the mapping of core competences in private sector R&D[1] was linked to an analysis of industry sectors that can be said to have a business stronghold[2]. The analysis is designed to serve as part of the empirical background for the identification of key positions of strengths in Danish research and industry, and for an assessment of how these strengths should be maintained and developed in the coming years.

Core R&D competences and business strongholds are connected in the sense that the business strongholds convey an image of the productivity advantages that Danish industry holds today, and which have been developed on the basis of the knowledge embedded in the industry. By comparison, core R&D competences offer an image of strengths in the private sector's knowledge base as it looks today. And further the importance of the analysis is underlined by the fact that the business strongholds held by the Danish industry today is not necessarily the same that should form the basis for the future Danish economy. As such, the analysis of core R&D competences provides indications of which technological areas are likely to form the basis for business strongholds in Danish industry in the coming years.

The importance of the private sector research is demonstrated by the fact that private R&D is a key engine of knowledge production, innovation and, ultimately, economic growth. For instance, in 2010, Danish industry invested 36.9 billion Danish kroner, or 2.1 percent of the gross national product, in research and development.

Moreover, private sector research is an important complement to public sector research: it can both utilise results and methods developed by public research institutions and stimulate public science to pursue new research directions.

In this light the purpose of the present analysis is not to show causality between a high level of R&D competence and increased productivity, but to point out that the areas where Denmark currently holds core R&D competences could be used strategically to set the direction for innovation and growth in the Danish economy.

The present report summarises the findings from the two sub-reports commissioned by the Danish Agency for Science, Technology and Innovation:

- DAMVAD (2012). *Core competences in Danish private sector R&D*.
- DAMVAD (2012). *Danish knowledge and business strongholds*.

[1] Core competences are defined as research areas in which R&D by Danish firms has an above-average impact on the international research front. Please refer to box 2.1 for a detailed description.

[2] Business strongholds are defined as sectors where productivity is at least 20 pct. above average productivity among Denmark's trading partners. Please refer to box 2.1 for a detailed description.

1.2 Main conclusions

The report presents the findings in a combined setting that allows for new conclusions and results to be drawn. The key findings of the report are:

- The top ten of the 102 core competences in Danish private sector R&D is dominated by life science.
- Large firms dominate core R&D competences.
- Core R&D competences are based on contributions from firms in several industry sectors.
- Companies that contribute to core competences in R&D are behind 25 pct. of the total export.
- Companies that contribute to core competences in R&D have a higher productivity and are more R&D active.

1.3 Key findings

The top ten of the 102 core competences in Danish private sector R&D is dominated by life science.

In total, Danish industry has had an above-average impact compared to other countries in 102 (21 percent) of the 486 research areas examined using publication and patent data from the past decade.

56 of the 102 core competences have been identified based on publication data; the remaining 46 were identified using patent data.

The 102 core R&D competences represent the research areas in which Danish private R&D has showed exceptional performance compared to

TABLE 1.1

Top ten core R&D competences measured by relative impact and volume

	Rank according to the impact		Rank according to the Volume	
Rank	Core R&D competence	Relative Impact	Core R&D competence	No. of patents/ publications
1	Biochemistry Molecular Biology / Life Sciences and Biomedicine - Other Topics & Cell Biology (Pub 1)*	4.91	Pharmaceuticals (Pat 36)*	1195
2	Surgery / Transplantation (Pub 2)	3.95	Engines, pumps, turbines (Pat 29)	779
3	Audio-visual technology / Electrical machinery, apparatus, energy (Pat 1)	3.32	Biotechnology (Pat 40)	764
4	General & Internal Medicine / Research & Experimental Medicine (Pub 3)	3.20	Organic fine chemistry & Pharmaceuticals (Pat 26)	614
5	Chemistry / Engineering (Pub 4)	2.41	Biophysics (Pub 49)	390
6	Electrical machinery, apparatus, energy / Semiconductors (Pat 2)	2.11	Electrical machinery, apparatus, energy (Pat 37)	325
7	Audio-visual technology / Semiconductors (Pat 3)	2.04	Agriculture (Pub 53)	315
8	Health Care Sciences and Services / Public, Environmental and Occupational Health (Pub 5)	1.82	Thermal processes and apparatus (pat 19)	313
9	Veterinary Sciences / Zoology (Pub 6)	1.81	Neurosciences & Neurology / Pharmacology & Pharmacy (Pub 37)	310
10	Transport (Pat 4)	1.75	Organic fine chemistry (Pat 39)	305

**) Pub 1 indicates that the core R&D competence mentioned here is based on publication data and that it is competence number 1. Likewise Pat 36 indicate the core R&D competence number 36 and that it is based on patent data*

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other OECD countries. Table 1.1 shows the top ten of these 102 core R&D competences, measured in terms of their relative impact on the international research front and in terms of volume (that is, the number of publications and/or patents behind the core competences). The top ten R&D core competences are dominated by life science related research topics, but information and communication technology and classical engineering fields are also represented.

The distribution of all 102 core competences across research fields is summarised in table 1.2. The table shows how patent and publication based core competences are unevenly distributed between the research fields and also how they are complementary to each other, indicating that some research fields are dominated by patenting activity and others by scientific publications.

The two research fields in which Danish private R&D performance is outstanding are *Biotechnology* and *Food Science & Technology*; both of these fields hold core R&D competences in 38 percent of the research areas that constitute the field.

The analysis shows that publications and patents offer a window on firms' R&D activities that can be used in a systematic analysis of core competences in Danish private sector R&D. Moreover, the two types of data appear to be highly complementary: 678 firms have contributed to core competences in private sector R&D; of these, just 128 firms (19 percent) have contributed to both publication and patent based core competences. The remaining firms have only contributed to publication *or* patent based core competences.

TABLE 1.2

Core competences, by research field

Research field	No. of patent based core competences	No. of publication based core competences
Chemistry	6	1
Materials chemistry	6	4
Biotechnology	3	7
Pharmaceuticals	2	3
General medicine	0	19
Food science & technology	2	6
Enviromental technology	2	5
Instruments	2	4
Civil & mechanical engineering	13	5
Information technology	10	2
Social sciences	0	0
Total	**46**	**56**

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Large firms dominate core competences.
The analysis indicates that large international firms contribute to a disproportionate number of core competences. This indicates that large firms are key drivers in leading-edge research areas in Danish industry.

Table 1.3 list the top ten firms that contributed to a R&D core competence. Among these ten firms are the pharmaceutical firm and other firms that build their business on a strong R&D tradition. It should however be noted that the methodology used to identify core competences (i.e. using publication and patent data) may be biased towards large firms, as these companies have greater resources at their disposal to invest in publishing and patenting.

TABLE 1.3

Top ten firms by number of core competences that the firms contribute to

	No. of core competences
Novo Nordisk	64
Danfoss	31
Danisco	27
Lundbeck	27
Grundfos Biobooster	22
Novozymes	21
Chr. Hansen	19
Neurosearch	18
Carlsberg	17
Coloplast	16
NKT Research	16
Haldor Topsøe	15
Nycomed	15
VIKING Life-Saving Equipment	15
ALK-Abelló	14

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Core R&D competences are based on contribution from firms from several sectors, and are not linked to a specific industry.

The analysis of different industry sectors' contributions to core competences in private sector R&D reveals that firms from several sectors often contribute to the same core competences. As the data in table 3.9 show, we find that the knowledge produced in the firms representing for instance the mechanical engineering sector and the food, drink and tobacco sector finds use in several, common core R&D competences. As such, the scientific development within a given research field can bring companies from different sectors together in a research area of joint interest. It is possible that knowledge produced in different industry sectors is applied to address different scientific and technical problems within the same research area.

Companies that hold a business stronghold and/or a core R&D competence are not necessarily similar.

The characteristics of the firms that hold a business stronghold are not necessarily the same as the factors that distinguish firms that contribute to core R&D competences. The differences lies in the fundamental basis of a business stronghold as compared to a core R&D competence. The fundamentals for having a business stronghold are related to how the factors that support the productivity of a firm or industry sector are influenced by society and the surrounding world. As stated above, these factors are not necessarily the same for firms and sectors holding a core R&D competence. For core R&D competences, three factors dominate the picture: the scientific research agenda, competition in the research arena, and scientific traditions within the research area.

TABLE 1.4

Number of companies in knowledge and business strongholds

Group	Core competences	Business stronghold	No. of companies	No. of employees
Core R&D competence & business stronghold	Yes	Yes	67	19,654
Core R&D competence only	Yes	No	437	112,114
Core R&D competence only*	Yes	No	341	105,722
Business stronghold only	No	Yes	20,411	130,470
No core R&D competence & no business stronghold	No	No	112,400	1,887,388
All			133,315	2,149,626

**) excluding the R&D industry.*

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These three factors all have influence on the extent to which the sector can stand out and contribute to a core R&D competence. As table 1.4 indicates, the conditions for a sector to perform exceptionally on both arenas are rare; only 67 of our 678 firms contribute to a core R&D competence while simultaneously being in an industry sector with a business stronghold.

Companies that contribute to core competences in R&D are behind 25 pct. of the total export.

The companies that contribute to core competences in R&D represent less than one percent of the total number of companies in Denmark. They account, however, for a sizeable amount of the activities in the Danish private sector, or 6 percent of all employees, 13 percent of total revenue, and 25 percent of total exports.

Companies that contribute to core competences in R&D have a higher productivity.

Productivity in companies that contribute to a core competence in R&D is almost 30 percent higher than in other companies. The differences in productivity levels may be due to differences in underlying, company-specific characteristics. Companies that contribute to core competences in R&D are generally larger and more internationally oriented, and their employees have a higher level of education; these are all factors that are known from economic theory to affect productivity positively.

Companies that contribute to core competences in R&D are more R&D active

The companies that contribute to knowledge strongholds are not surprisingly more R&D active than other companies. To a larger extent, they have their own, in-house R&D departments. Moreover, more than 10 percent of their employees work with R&D. By comparison, the corresponding proportion of employees in other companies is less than 5 percent.

2 Data and approach

This section gives a brief description of the data and approach used in the tow above mentioned report.

Strengths in private sector R&D were identified using data on patent applications and scientific publications by firms. Core competences in R&D were defined as research areas where Danish firms have, collectively speaking and over the past decade, had an above-average impact on the international research front (see box 2.1 and 2.2).

The core R&D competences identified were also linked to register data on Danish firms and to a list of business strongholds in the Danish private sector identified by the Ministry of Business and Growth in early 2012. The aim of this part of the analysis was to explore the economic importance of private sector core competences in R&D.

Box 2.1. Measuring core competences in R&D

Core competences are defined as research areas in which R&D by Danish firms has an above-average impact on the international research front.

Private sector R&D is analysed using data on patents and publications by Danish firms during the period 2000 to 2011 (both years included). The impact of firms' patents and publications is measured using data on citations. Moreover, to constitute a core competence, Danish firms must have had above-average impact within a research area when assessed over the entire period of study, i.e. the past decade. This approach was chosen to ensure that the analysis only identifies *established* core competences, i.e. research areas that have a sufficiently robust foundation to warrant dedicated initiatives to lift Danish research and innovation further.[3]

More precisely, core competences in R&D are defined as research areas in which Danish firms' publications or patents have an above average quality (measured by citation data) relatively to other OECD countries (measured as relative impact above 1) and a volume greater than 10 publications or patents over the past decade.

It should be noted that there are large differences across both firms and industry sectors in the use of patents and scientific publications. Thus, some firms and some sectors will be overrepresented in an analysis of this type, while others will be underrepresented. On the whole, however, publications and patents are valuable sources for systematic identification of core competences in R&D.

[3] The technique applied in this study can also be used to identify emerging core competences, i.e. research areas in which Danish firms have had an above-average impact over a shorter period of time, e.g. three years. The ten-year period was selected in this study to ensure a certain level of continuity and robustness in the core competences identified.

Box 2.2. What are business strongholds? (as defined by the Ministry of Business and Growth)

Business strongholds are defined as sectors where the productivity is at least 20 percent above average productivity among Denmark's trading partners.

The Ministry of Business and Growth has identified 14 industries where Danish industries can be said to have a business stronghold. An industry sector has a stronghold if the productivity in the industry, relative to average productivity in Denmark, is 20 percent higher than the relative productivity in the same industry among Denmark's trading partners. In that case, Denmark can be said to hold a comparative advantage in that industry.

Please note that this does not necessarily mean that *all* companies in the 14 industries with a business stronghold have a comparative advantage, but that, on average, each industry does. In other words, business strongholds are defined at industry level whereas core competences in R&D are identified at the level of individual companies.

For more information on the data and methods behind the findings presented in the summary report, please see chapter 5 of this report or the background reports[4] that it draws on.

2.1 All patents by Danish industry

The data collection revealed a total of 13,696 patent applications assigned to a total of 803 Danish firms during the period 2000 to 2011 (both years included).

TABLE 2.1
Main results from patent search

	Results
No. of firms included in the search	3,095
No. (percentage) of these firms that had filed patent applications	803 (26%)
Total no. of patent applications	13,969
Ave. no. of patent applications by firm	22
Min. no. of patent applications by firm	1
Max. no. of patent applications by firm	2,144

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Figure 2.1 shows the development in the number of patent applications by year of application. The graph indicates a small, overall increase over time in the number of patent applications by Danish firms.

Please note that since only a part of the patent applications filed in 2010 and 2011 were available at the time of data collection in spring 2012, data from these years have been excluded from the figure 2.1. This is due to the time lag that is enforced by the patent filing procedure. A patent application is normally kept secret (and therefore does not appear in patent searches) for the first 18 months after filing, to allow for the patent examiners' initial review of the novelty of the patent and for possible infringement in the patent.

[4] DAMVAD (2012). *Core competences in Danish private sector R&D* and *Danish knowledge and business strongholds*.

Table 2.2 lists the distribution of firms with patent applications, categorised by the number of patents that they filed for. It shows that 7 percent of firms have filed 72 percent of the patent applications assigned to Danish firms during the period of study.

TABLE 2.2

Firms, by number of patents

	No. of firms	Share of firms	No. of patents	Share of patents
1-5 patents	537	67%	1,080	8%
5-10 patents	103	13%	650	5%
10-50 patents	112	14%	2,229	16%
50-500 patents	45	6%	5,702	42%
> 500 patents	6	1%	4,035	30%
Total	**803**	**100%**	**13,696**	**100%**

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2.2 All publications by Danish industry

The data collection revealed a total of 15,157 scientific publications authored or co-authored by a total of 650 Danish firms during the period 2000 to 2011 (both years included).

TABLE 2.3

Main results from publication search

	Results
No. of firms with publications	650
Total no. of publications	15,567
Ave. no. of publications by firm	31
Min. no. of publications by firm	1
Max. no. of publications by firm	3,188

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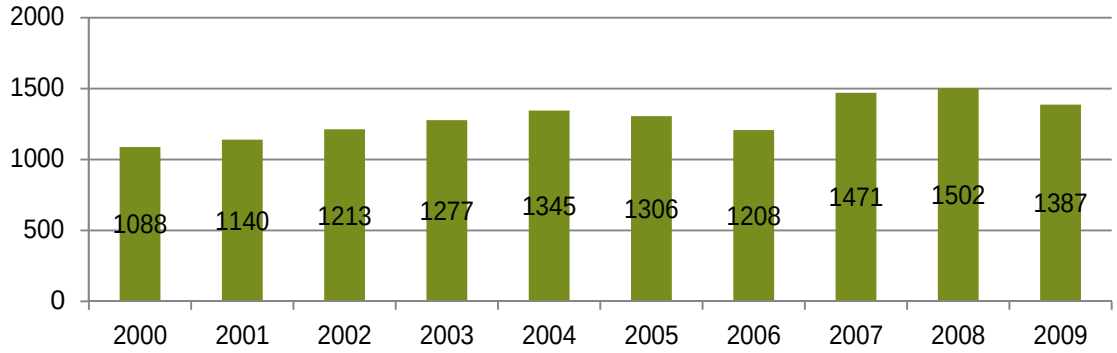
While figure 2.2 shows the development in the number of publications by year of publication, table 2.4 lists the distribution of firms with publications, categorised by the number of publications that they have authored or co-authored. It shows that 7 percent of firms have authored or co-authored 76 percent of the publications by Danish firms during the period of study.

FIGURE 2.1.

Number of patent applications by Danish firms, by year (2000-2009)



Note: note that since only a part of the patent applications filed in 2010 and 2011 were available at the time of data collection in spring 2012 data from these years has been excluded from the figure

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TABLE 2.4

Firms, by number of publications

	No. of firms	Share of firms	No. of pubs.	Share of pubs.
1-5 publications	406	62%	772	5%
5-10 publications	69	11%	421	3%
10-50 publications	131	20%	2,398	16%
50-500 publications	38	6%	5,135	34%
> 500 publications	6	1%	6,431	42%
Total	650	100%	15,157	100%

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2.3 Using patents and publication data together

Looking at patent data and publication data together reveal that publications and patents offer a window on firms' R&D activities that can be used in a systematic analysis of core competences in Danish industry R&D. Moreover as indicated in table 2.5 below, the two types of data appear to be highly complementary: 678 firms have contributed to core competences in private sector R&D; of these, just 128 firms (19 percent) have contributed to both publication and patent based core competences. The remaining firms have only contributed to publication *or* patent based core competences, indicating that publication and patent data capture different aspects of knowledge production in industry.

TABLE 2.5

Firms that could be linked to a company registration number and which have contributed to core competences, by source of contribution

Category	No. of firms
Firms that have contributed to both publication- and patent based core competences	128 (19%)
Firms that have contributed to publication based core competences only	254 (37%)
Firms that have contributed to patent based core competences only	296 (43%)
Total number of firms	678 (100%)

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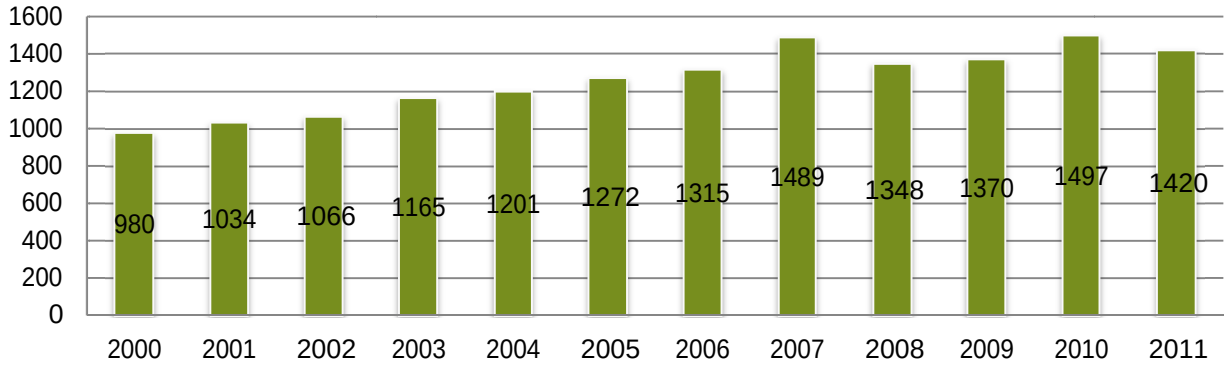
FIGURE 2.2

Number of publications by Danish firms, by year (2000-2011)



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3 Core competences in private R&D

This chapter summarises the findings of the mapping of core R&D competences, research fields and the link between the two, viewed in the light of contributing industry sectors and firms.

- The 102 core R&D competences represent the research areas in which Danish private R&D has showed exceptional performance compared to other OECD countries.
- Large firms make a disproportionately large contribution to core competences in private sector R&D in Denmark.
- Danish firms engage in a higher degree of research and publishing or patenting in some areas relative to others.
- Patents and publications are complementary sources of insight into R&D core competences in private sector R&D.
- A few industry sectors are characterized by having a small number of firms that contribute to a large number of core competences.

As mentioned in chapter 2, core competences are defined as research areas in which R&D by Danish firms has an above-average impact on the international research front. Please refer to box 2.1 for a detailed description. Furthermore, as specified in chapter 2, the requirements for a core competence in R&D are that Danish firms' publications or patents must have combined relative impact higher than 1 and a volume greater than 10 publications or patents over the past decade.

3.1 Core competences

In total, Danish industry has had an above-average impact compared to other countries in 102 (21 percent) of the 486 research areas examined using publication and patent data from the past decade. These 486 research areas include 278 patent based and 208 publication based re-

TABLE 3.1

Number of core competences by research field

Research field	Patent based core competences			Publication based core competences		
	No. of core comps.	Total no. of research areas	Core comps. as % of all research areas	No. of core comps.	Total no. of research areas	Core comps. as % of all research areas
Chemistry	6	23	26%	1	2	50%
Materials chemistry	6	23	26%	4	7	57%
Biotechnology	3	10	30%	7	16	44%
Pharmaceuticals	2	7	29%	3	11	27%
General medicine	0	2	0%	19	55	35%
Food science & technology	2	14	14%	6	7	86%
Enviromental technology	2	9	22%	5	25	20%
Instruments	2	41	5%	4	7	57%
Civil & mechanical engineering	13	84	15%	5	13	38%
Information technology	10	54	19%	2	14	14%
Social sciences	0	11	0%	0	51	0%
Total	**46**	**278**	**17%**	**56**	**208**	**27%**

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search areas that are derived from standard classifications of patent and publication data. There is some degree of overlap between the patent and publication based classification of research areas, as many research areas lend themselves to both patenting and publishing.

56 of the 102 core competences have been identified based on publication data; the remaining 46 were identified using patent data.

For a full list of all 102 core competences and how they are distributed across the 11 research fields, please see appendix 1 of this report.

TABLE 3.2

Distribution of core competences across research areas based on publications and patents

	Results
No. of publication based research areas examined	208
No. of publication based core competences identified	56 (27%)
No. of patent based research areas examined	278
No. of patent based core competences identified	46 (17%)
Total no. of research areas examined	486
Total no. of core competences identified	102 (21%)

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These 102 core competences cover a wide variety of scientific areas. To provide an overview of the general concentration of Danish firms' R&D competences, the 102 core competences have been aggregated under 11 different research fields.

The distribution of core competences across the 11 research fields is summarised in table 3.1.

More precisely, table 3.1 shows the number of core competences within a given research field alongside with the total of research areas (or potential core competences) within that field. For example: there are 23 patent based research areas within the research field "Chemistry"; Danish firms' R&D has met the requirements for constituting a core competence in 6 of these research areas (or 26 percent of the total set of research areas).

For a detailed presentation of all 102 core competences, please see the background report DAMVAD (2012), *Core competences in private sector R&D.*

As indicated by table 3.9, the number of competences that could potentially have been classified as a core competence is rather high for most of the research fields. Most research fields, core competences in R&D account for between 18 and 38 percent of all potential competences, though with some variation. The research field *Food science and technology* includes 8 (38 percent) core competences from a total population of 21 research areas constituting this research field. This share should be viewed in relation to the research field *Civil & mechanical engineering* where Danish firms hold 19 (18 percent) core competences among the 97 research areas that constitute the research field. These findings suggest that the closer to the full coverage that Danish private sector R&D gets, the better the firms perform relative to the international research frontier.

Looking across all research fields and taking both patent and publication core competences into account, the two fields in which Danish private sector R&D shows the best performance are *Biotechnology* and *Food Science & Technology*; both of these fields hold core R&D competences in 38 percent of the research areas that constitute their field.

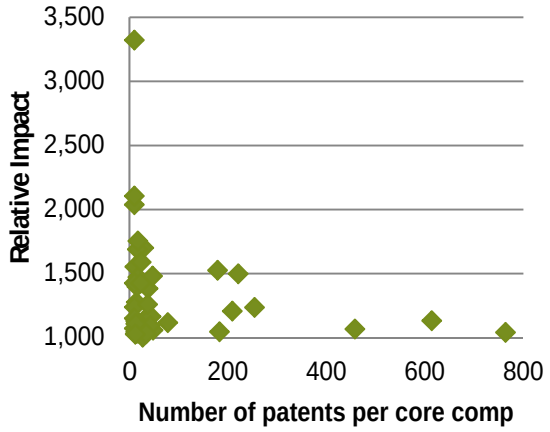
3.2 Relationship between impact and volume for core competences

The number of publications or patents varies greatly across research areas. This may be because Danish firms engage in a higher degree of research and publishing or patenting in some areas relative to others. These differences may however also reflect the fact that some research areas (e.g. chemicals and pharmaceuticals) are significantly more publication and/or patent intensive that others.

It is therefore important to consider the volume i.e. the number of publications or patents that lie behind core competences in Danish private sector R&D.

Figure 3.1 shows the relationship between the volume and the relative impact of core competences identified based on patent data.

FIGURE 3.1
Volume versus relative impact for patent based core competences



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Moreover, the figure shows that core competences based on a larger volume of patents tend to have lower relative impact. This could be caused by the fact that patents in the specific area generally speaking have lower levels of impact; or it may be that the area holds a high number of patents with no or few citations that cause the average impact to be lower, even though some firms or patents have a high impact. The figures behind these numbers show that for the three core R&D competences[5] that have a patent volume greater than 400, there are a large number of patents receiving none or few citations.

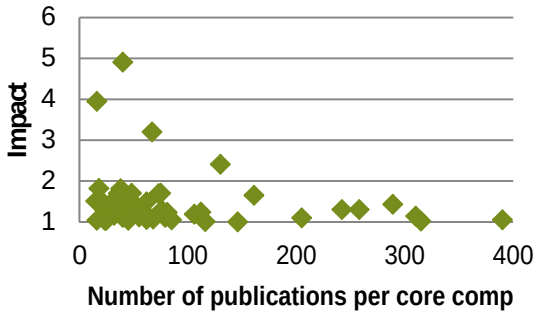
Regardless, a greater volume indicates that the knowledge base underlying the core competence is more robust and typically also distributed across a larger number of firms than for core competences based on a small number of patents.

Similarly, figure 3.2 shows the relationship between volume and relative impact for the core competences based on publication data. Again, the figure indicates that core competences based on a larger volume of publications tend to have lower relative impact.

[5] Pharmaceuticals (Pat 36), Organic fine chemistry / Pharmaceuticals (Pat 26) and Biotechnology (Pat 40).

FIGURE 3.2

Volume versus relative impact for publication based core competences



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3.3 Firms that contribute to core competences in R&D

As indicated by table 3., 486 (75 percent) of the Danish firms that have published scientific articles during the past decade have also contributed to one or more of the core competences identified using publication data. The table also shows that 416 (52 percent) of the firms that have filed for patents during the same period have contributed to one or more of the core competences identified using patent data.

TABLE 3.3

Firms that have published and/or patented

	Results
No. of firms with publications	650
No. of firms with publications that have contributed to core competences	486
No. of firms with patents	803
No. of firms with patents that have contributed to core competences	416

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The analysis also indicates that patents and publications are complementary sources of insight into core competences in private sector R&D.

In total, 678 unique firms that could be linked to a company registration (i.e. CVR) number have contributed to the core competences (cf. table 3.4)[6]. Just 128 of these firms (19 percent) have contributed to both publication and patent based core competences.

Meanwhile, 254 (37 percent) have contributed to publication based core competences alone, while 296 (43 percent) have contributed to patent based core competences alone.

The distribution on how many core competences that the firms contribute to is highly skewed. 73 percent of the firms contribute to one or two R&D core competences while approximate 4 percent of the firms contributed to more than 10 core competences. These findings indicates that even though the more R&D driven firms plays a major role in forming and contributing to the core competences a large number of firms with less R&D focus still contribute to the R&D core competences. Among these firms the results shows firms very specialized technology wise and firms being characterized by belonging to sectors with a weaker research tradition.

[6] The difference in the number of firms listed in tables 4.5 and 4.6 is caused by the fact that not all firms contributing to patents or publications could be linked to a company registration (CVR) number. As a result, a number of firms (e.g. firms involved in mergers or acquisitions or that have been closed down at some point in time during the period from 2000 to 2012) are not included in the analysis behind table 4.6.

TABLE 3.4

Firms that could be linked to a company registration number and which have contributed to core competences, by source of contribution

Category	No. of firms
Firms that have contributed to both publication- and patent based core competences	128 (19%)
Firms that have contributed to publication based core competences only	254 (37%)
Firms that have contributed to patent based core competences only	296 (43%)
Total number of firms	678 (100%)

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Finally, the analysis indicates that large firms make a disproportionately large contribution to core competences in private sector R&D in Denmark. Table 3.5 lists some examples.

On the one hand, this may reflect the important contribution of such large, research-intensive firms to research and innovation. On the other hand, as described in section 1.5 of Core competences in private sector R&D in Denmark, the method used in the identification of core competences is also likely to be biased toward larger firms with more resources to invest in patenting and scientific publishing.

For a full list of the companies that contribute to core competences, please see the background report DAMVAD (2012), *Core competences in private sector R&D in Denmark*.

TABLE 3.5

Top ten firms by number of core competences that the firms contribute to

	No. of core competences
Novo Nordisk	64
Danfoss	31
Danisco	27
Lundbeck	27
Grundfos Biobooster	22
Novozymes	21
Chr. Hansen	19
Neurosearch	18
Carlsberg	17
Coloplast	16
NKT Research	16
Haldor Topsøe	15
Nycomed	15
VIKING Life-Saving Equipment	15
ALK-Abelló	14

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3.4 Industry sectors and core competences

This section examines the relationship between core competences in R&D and industry sectors, with a view to explore industries' contributions to core competences in R&D and later the connection between the industry sectors and research fields.

The findings in this section shows that firms belonging to sectors that contribute to a large number of core R&D competences have a more diverse knowledge base than firms in sectors that contribute to few core R&D competences. The number and diversity of the R&D competences that industry sectors contribute to can be exemplified by the mechanical engineering sector. This is a generic sector as such, but as evidenced by appendix 2 (table AP2.34), firms in this sector

contribute to 21 different core competences as diverse as *Instruments & Instrumentation* and *Environmental Sciences, Ecology & Water Resources*.

Table 3.6 shows the relationship between industries, the number of firms from each industry that contribute to core R&D competences, and finally the number of core competences that these firms contribute to. The table shows a close connection between the number of firms and the number of core competences that these firms are associated with. Furthermore, the table illustrates that some industries are characterized by a small number of firms that contribute to a large number of core competences; for instance, 13 firms in the chemical sector are associated with 42 different core competences. In this case, the number of core competences illustrates the diversity of the knowledge base held by these firms.

The sectors listed in table 3.6 are divided into three different groups, based on the relationship between the number of firms and the number of core competences. The hypothesis is that sectors that contribute to few core competences operate in research fields that hold few possibilities for diversification, which again leads to rather specialized research output. Conversely, sectors which contribute to a large number of core competences engage in research areas with more generic characteristics.

The firms are divided into the following three groups: Group one is characterized by a large number of firms operating in and contributing to relatively few core competences. The second (middle) group includes sectors where the number of firms and core competences that they contribute to are similar. Finally, a third group contains sector where a relatively low number of firms contribute to a large number of core competences.

The third group is here exemplified by the sectors *Chemicals* and *Pharmaceuticals*, which are characterized by containing many large firms and only few small or medium sized enterprises. The sector *Chemicals* is dominated by firms like Hempel and Novozymes, while Novo Nordisk and Nycomed are representatives of the *Pharmaceutical* sector. The mentioned firms are all characterized by contributing to many core competences and, as hypothesized, operating in research fields with substantial possibilities for diversification and the generic application of technologies.

The size and content of the *R&D* industry sector should be noted. The R&D sector as such contains a broad variety of firms that – based on what they sell – belong to a wide ranges of industries, including e.g. biotechnology, pharmaceuticals, energy and water and waste. Moreover, most of the firms assigned to the R&D sector are small or medium sized enterprises.

TABLE 3.6

Industries, firms and the number of core competences these firms contribute to.

Sector	No. of firms with core comps.	No. of core comps.
R&D	129	134
Pharmaceuticals	21	69
Other / unknown e.g. holding companies	90	67
Consultancy and advisory services	111	57
Plastics, glass and concrete	34	50
Mechanical engineering	76	46
Chemicals	13	42
Electronics	39	39
Food, drink and Tobacco	33	36
IT and information services	47	27
Manufacturing of electrical equipment	24	25
Water and waste	7	18
Other business services	24	17
Metals	27	16
Energy	6	12
Agricultural, forestry and fishery	12	10
Transport and transportation equipment	11	9
Publishing, TV and radio	8	8
Construction	6	5
Natural resource extraction	7	5
Wood, paper and printing	7	5
Other services	2	4
Healthcare	4	4
Textile and leather	4	2
Other manufacturing	24	1

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Research fields and sectors

While table 3.6 gives an overview of the relationship between industries, firms and core competences, table 3.7 shows the connection between the 10 (social sciences has been excluded since no core R&D competence has been identified in this research field) aggregated research fields described in section 3.1 and industry sectors. More precisely, the table lists the top five contributing industries for each research field. Industries are ranked according to the number of firms in each industry that contribute to the core competences associated with the research field. It is evident from the table that some industries (e.g. *Consultancy and advisory services*) engage in R&D which contributes to a wide range of research fields, while other industries tend to be more specialized within one or two research fields (e.g. *Manufacturing of electrical equipment*).

Furthermore, the table (3.9) shows that despite multiple connections between industry sectors and research fields, there still seems to be a clear definition of labor among the industry sectors. The life science dominated research fields are populated by sectors that traditionally operate within these areas. Likewise, the more traditional engineering research fields are dominated by sectors that by tradition have this area of interest. These findings indicate that the diversity of research areas in which the firms of each individual sector operate are limited to scientific and technological areas where the barriers for spillovers from the parent knowledge base is limited. For example, the barriers for knowledge spillovers in the research field of *Food Science & Technology* are minimal for firms from the *Pharmaceutical* sector or from the *Food, drink and tobacco* sector.

Table 3.7 and 3.8 below show an example of the connection between industry sectors and core R&D competences. The tables for the remaining sectors are found in Appendix 2 of this report. The two tables list the total number of core R&D competences along with the top five core R&D competences that firms in the *Food, drink and tobacco* sector contributed to by their patenting or publishing. Along with the number of core R&D competences, the table shows the number of firms with origin in the sector that contributes with the said share of the patents/publications within the given R&D core competence. The later illustrates the influence of the sector on the given core competence and to what extent the sectors' contribution to a core competence is based on multiple firms or on a single firm. The number of firms involved in the knowledge production behind the core competence gives an indication of how firmly grounded the core competence is in the given sector. In this view, a core competence that is based on contributions from just a few firms is less stable or robust than a core competence supported by a large number of firms.

TABLE 3.7

The *Food, drinks and tobacco* sector linked to publication based core competences

No. of core competences	Core competence ID	Core competence description	No. of firms	Share of patents behind core competence
17	Pub 22	Fisheries	4	34%
	Pub 24	Nutrition & Dietetics; Food Science & Technology;	5	27%
	Pub 46	Food Science & Technology; Microbiology;	2	22%
	Pub 53	Agriculture	9	18%
	Pub 13	Integrative & Complementary Medicine	1	13%

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TABLE 3.8

The *Food, drinks and tobacco sector* linked to patent based core competences

No. of core competences	Core competence ID	Core competence description	No. of firms	Share of patents behind core competence
19	Pat 23	Macromolecular chemistry, polymers	1	59%
	Pat 9	Food chemistry	12	42%
	Pat 43	Food chemistry / Pharmaceuticals	3	42%
	Pat 6	Macromolecular chemistry, polymers / Organic fine chemistry	1	31%
	Pat 28	Basic materials chemistry	2	10%

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TABLE 3.9 RESEARCH FIELDS AND INDUSTRIES

Research field*	No. of industries	Industries	No. of firms	No. of core comps.
Biotechnology	18	R&D	130	10
		Pharmaceuticals	33	10
		Food, drink and tobacco	20	8
		Chemicals	16	9
		Consultancy and advisory services	14	5
Chemistry	17	R&D	40	7
		Mechanical engineering	17	2
		Pharmaceuticals	15	6
		Consultancy and advisory services	14	3
		Chemicals	12	7
Civil & Mechanical engineering	24	Mechanical engineering	137	13
		Plastics, gas, concrete	54	13
		Manufacturing of electrical equipment	36	9
		Electronics	28	7
		Metals	28	7
Environmental technology	15	Consultancy and advisory services	38	6
		R&D	26	6
		Mechanical engineering	19	6
		Food, drink and tobacco	15	3
		Pharmaceuticals	8	3
Food Science & Technology	10	Food, drink and tobacco	25	5
		R&D	23	7
		Pharmaceuticals	16	8
		Mechanical engineering	8	3
		Chemicals	5	5
Instruments	14	R&D	29	5
		Electronics	13	4
		Manufacturing of electrical equipment	11	5
		Other manufacturing	11	1
		Consultancy and advisory services	11	5
Materials chemistry	19	R&D	43	9
		Consultancy and advisory services	32	9
		Plastics, gas, concrete	23	8
		Mechanical engineering	21	6
		Chemicals	14	6
Pharmaceuticals	13	R&D	52	5
		Pharmaceuticals	21	5
		Food, drink and tobacco	8	2
		Chemicals	4	2
		Consultancy and advisory services	4	2
General medicine	12	Pharmaceuticals	38	17
		R&D	18	62
		Electronics	10	5
		Consultancy and advisory services	7	4
		Chemicals	4	2
Information technology	14	IT and information services	36	8
		Electronics	30	6
		Consultancy and advisory services	18	5
		Mechanical engineering	17	6
		R&D	16	5

*) Social sciences have been excluded since no core R&D competence has been identified in this research field.

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4 Link between core R&D competences and business strongholds

This section focuses on the relationship between the core competences in private sector R&D examined in chapter 2 with register data on Danish companies and with the business strongholds identified by the Danish Ministry of Business and Growth, as introduced in chapter 1 of this report.

The essential idea behind this analysis is that companies that contribute to core R&D competences have a potential to exploit their position within the core competence research areas to establish, support and/or develop a Danish business stronghold. A business stronghold is understood here as an industry sector, in which Danish firms hold a comparative advantage when compared to other countries.

Against this background, the main purpose of the analysis is to investigate: (i) the significance of firms that contribute to core R&D competences for the Danish economy, and (ii) the relationship between core R&D competences and business strongholds.

Caution should be exercised in concluding on the causal relationship between core R&D competences and business strongholds. Thus, a core R&D competence may arise on the basis of a business stronghold, or vice versa – but this is not necessarily the case. More in-depth analysis is required in order to generate conclusions regarding this causal relationship, and the results presented in this chapter should therefore be interpreted accordingly.

The key findings of this part of the study are presented below.

Companies that contribute to core R&D competences are relatively large and important for the Danish economy

67 percent of the companies, which contribute to a core R&D competence and are operating in a business stronghold, are medium or large sized companies. For companies without a business stronghold, the same number is 3 percent. Even though the companies which contribute to core R&D competences represent less than one percent of the companies in Denmark, they account for a sizable amount of the activities in the Danish private sector: 6 percent of the employees, 13 percent of the revenue and 25 percent of the export.

Companies which contribute to core competences have a higher productivity and have more R&D activities than other companies.

The productivity in companies contributing to one or more core R&D competences is almost 30 percent higher than in other companies. Companies which are operating in an industry with a business stronghold are however, on average, not more productive than companies operating in other industries.

The differences in productivity levels may be due to differences in underlying company-specific characteristics. Companies that contribute to core R&D competences are larger; more internationally oriented and have a higher education level - all factors that are known from economic theory to affect productivity positively.

The companies that contribute to core R&D competences are, not surprisingly, more R&D active than other companies. They have to a larger extent than other companies their own R&D departments; moreover, more than 10 percent of their

employees work with R&D. For comparison, this figure is less than 5 percent in other companies.

The picture is complex when combining competences by research field or industry level.
Each research field consist of many competences with different impacts, see figures 4.6 and 4.7. The differences in size (as indicated by employment) of each research field are relative large. Moreover, some research fields are characterized by firms that patent and other fields by firms that publish see figures 4.4 and 4.5. The figures 4.8 and 4.9 highlight which industries have had the largest average impact the core R&D competences.

Linking core competences in R&D with business strongholds
The core R&D competences identified in the Danish private sector were linked to register data on companies' economic activities and R&D activities and to a list of the industry sectors in which Denmark has business strongholds, developed by the Ministry for Business and Growth.

The analysis grouped Danish firms into four groups:

(i) Group 1: Firms that *both* contribute to one or more core competences in R&D and are in an industry with a business stronghold.
(ii) Group 2: Firms that *only contribute to core competences* in R&D, but are not part of an industry with a business stronghold.
(iii) Group 3: Firms that *are part of an industry with a business stronghold*, but do not contribute to core competences in R&D.
(iv) Group 4: Firms that *neither* contributes to R&D core competences nor to an industry with a business stronghold.

Generally speaking, the data revealed no differences between firms that *both* contribute to one or more core competences in R&D and are in an industry with a business stronghold (group 1) and firms that *only contribute to core competences* in R&D, but are not part of an industry with a business stronghold (group 2).

Companies which are operating in an industry with a business stronghold are on average not more productive than companies operating in other industries. There seems, however, to be a positive relationship between productivity and being a part of the international research frontier (contributing to core competences).

TABLE 4.1
Number of companies in knowledge and business strongholds

Group	Group	Core competences	Business stronghold	No. of companies	No. of employees
Core R&D competence & business stronghold	1	Yes	Yes	67	19,654
Core R&D competence only	2	Yes	No	437	112,114
Core R&D competence only*	2*	Yes	No	341	105,722
Business stronghold only	3	No	Yes	20,411	130,470
No core R&D competence & no business stronghold	4	No	No	112,400	1,887,388
All				133,315	2,149,626

Statistics Denmark and DAMVAD 2012

4.1 Basic characteristics of firms

Danish companies are divided into four groups according to whether the firm contributes to one or more core competences in R&D and whether the firm is located in an industry where Denmark has a business stronghold (see table 4.1).

Only 67 companies in Denmark both contribute to a core R&D competence and at the same time operate in an industry with a business stronghold. This group includes 13 percent of all companies that contribute to one or more core R&D competences, and accounts for 15 percent of the employment in companies that contribute to one or more core R&D competences.

A particular challenge for large companies is that they may have activities in more than one industry. Large companies are often legally organized in a group consisting of several subsidiary companies. In some large companies, R&D activities are separated from the headquarters in a subsidiary company (with its own company registration number).

This is important for this analysis, since patents and publications are often registered by the headquarters, but produced in separate R&D subsidiaries. That is, the patents and publications are registered in the industry of the corporate headquarter, but the (labor and capital) resources required to produce the patents and publications are registered in another industry (typically the R&D industry).

Since the R&D industry in Denmark is not a business stronghold, large companies can, in principle, be present in both group 1 and 2. One attempt to deal with this has been made by excluding the R&D industry from group 2. Group 2 is then reduced to 341 companies (cf. table 4.1). Although a rough estimate, this is a more precise estimate of the number of companies that contribute to core R&D competences but do not operate in industries with a business stronghold. The remaining 96 companies are assumed to be corporations with subsidiaries in the R&D industry.

Companies that contribute to core competences in R&D (groups 1 and 2) are characterized by having a considerably larger share of medium and large sized companies compared to companies that do not contribute to any core R&D competences (groups 3 and 4).

TABLE 4.2

Companies by size (percent)

Group	Core R&D competence & business stronghold	Core R&D competence only	Core R&D competence only *	Business stronghold only	no core competence & no business stronghold
Micro (1-9)	9,090909	25,18519	22,1875	89,51546	82,00356
Small (10-49)	24,24242	31,85185	29,375	8,84817	14,84875
Medium (50-249)	33,33333	22,71605	23,75	1,415903	2,604093
Large (249+)	33,33333	20,24691	24,6875	0,220469	0,543594
Total	100	100	100	100	100
N	67	437	341	20411	112400

Statistics Denmark and DAMVAD 2012

67 percent of the companies that both contribute to core competences in R&D and operate in industries with a business stronghold (group 1) are medium or large companies. Less than one percentage of the companies that do not contribute to core competences in R&D (groups 3 and 4) are large companies (see table 4.2).

There seems to be a positive relationship between the size of a company and the probability of being at the international forefront of research and development. This is plausible, since research at an internationally high level is resource intensive.

Even though the companies that contribute to core competences represent less than one percent of the total number of companies in Denmark, they nonetheless account for a sizable amount of the activities in the Danish private sector, or 6 percent of all employees, 13 percent of the revenues, and 25 percent of exports (see figure 4.1).

4.2 Productivity

Productivity is crucial for the competitiveness of Danish companies and hence for growth and employment in Denmark.

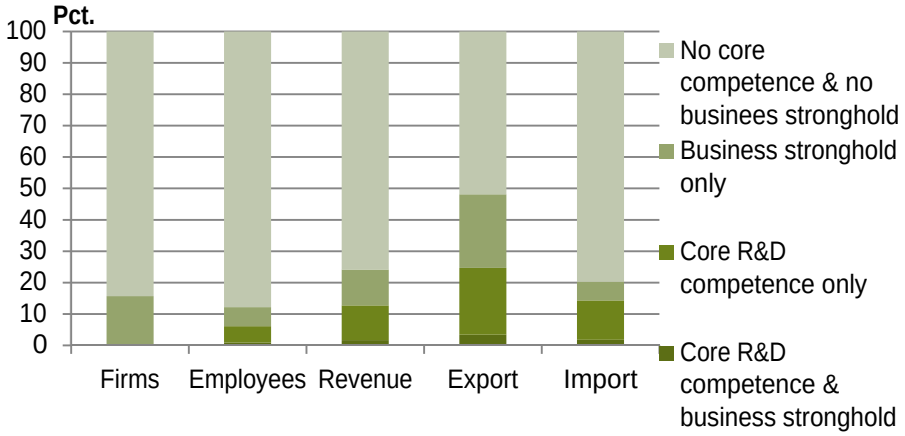
Value added pr. fulltime employed – the so-called labor productivity – is on average DKK 570.000 in Danish companies. However, there is considerable variation depending on whether the companies can be associated with a core R&D competence or a business stronghold.

The productivity in companies contributing to core competences in R&D (groups 1 and 2*) is almost 30 percent higher than in other companies. Companies that operate in an industry with a business stronghold are on average no more productive than companies operating in other industries.

It might sound counterintuitive that companies with a business stronghold are not on average more productive than other companies. Business strongholds are defined as industries where Den-

FIGURE 4.1

The share of the Danish economy that companies operating in a business stronghold or/and contributing to core R&D competences account for

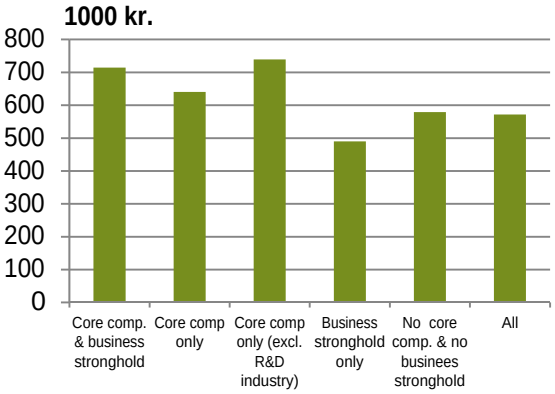


Statistics Denmark and DAMVAD 2012

mark has a relatively higher productivity than our trading partners. The textile industry is for example a business stronghold. The textile industry is not necessarily more productive than other industries in Denmark, but has a relatively higher productivity than the textile industries in our trading partners (see box 2.2 for the definition of business strongholds)

FIGURE 4.2

Average productivity



* excluding the R&D industry

Statistics Denmark and DAMVAD 2012

The higher productivity in groups 1 and 2 may reflect that these companies have developed a position of strength in R&D, which gives them a competitive advantage. It is however also possible that highly productive companies can afford the R&D necessary to develop a position of strength in R&D, and that the companies were highly productive in advance.

Groups 1 and 3 consist of companies that are located in an industry with a Danish business stronghold. It is noteworthy that companies that are also linked to core R&D competences (group 1) have a significantly higher productivity than companies that are not (group 3). It is particularly noteworthy that the productivity in group 3 is lower than the average productivity for all companies as a whole. First and foremost, this shows that there is a large degree of variation in the productivity level across companies located in industries with a business stronghold.

Additionally it can indicate that R&D on an international high level can contribute to high efficiency in companies. This hypothesis is supported by the fact that productivity in companies that contribute to core R&D competences, but who are not in industry with a business stronghold, is significantly above the overall productivity level for all companies.

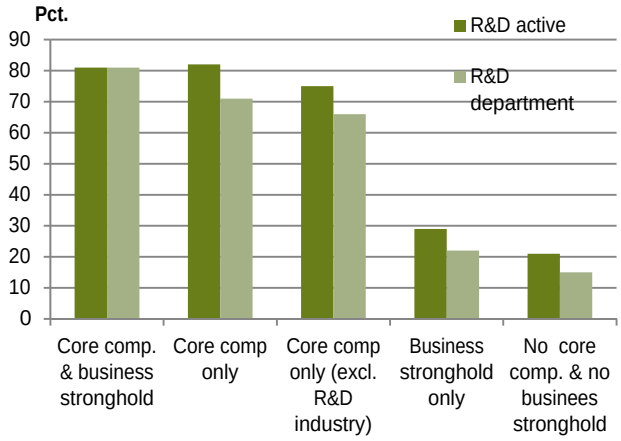
The differences in productivity levels may be due to differences in underlying company-specific characteristics. Companies contributing to core R&D competences (groups 1 and 2) are characterised by a number of special conditions. They are to a large extent big companies, which are globally based, have a large fraction of employees with a higher education, and have high capital intensity. For more information on this, please see table 3 in the background report DAMVAD (2012), *Danish business and knowledge strongholds*.

The general picture seems to be that considerable resources are required to obtain knowledge (publications and patents) on an international high level. There appears to be a positive relationship between productivity and contributing actively to the international research frontier. However, in order to isolate the effect from contributing to core R&D competences, it is necessary to control for the above mentioned conditions that affect productivity.

4.3 Research and development

The companies that contribute to core R&D competences are not surprisingly more R&D active than other companies.

FIGURE 4.3
R&D activities



Note: based on the Statistics Denmark's R&D statistics, which is based on a representative sample of around 4,000 companies, see table 4.1

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More than 80 percent of the companies contributing to core R&D competences (groups 1 and 2) are active in R&D. For companies that do not contribute to core R&D competences (groups 3 and 4), less than 30 percent are R&D active (see figure 4.3). Companies contributing to core R&D competences have, to a larger extent, their own, in-house R&D departments.

The same picture emerges when looking at the fraction of employees working with R&D in the companies. More than 10 percent of the employees are working with R&D in companies in groups 1 and 2. For companies in groups 3 and 4, the corresponding figure is less than 5 percent.

R&D cooperation

The companies that contribute to core R&D competences are cooperating on R&D with external actors on a large scale. Interestingly, the companies that are also located in an industry with a business stronghold (group 1) cooperate to a larger degree with other firms and actors from abroad. The ones not located in a business stronghold (group 2) cooperate more with public actors, which especially can be ascribed to the R&D industry's cooperation with the public sector (see table 4.3).

TABLE 4.3
R&D collaboration (percent of R&D active firms)

Group	Collaboration with private sector	Collaboration with public sector	International collaboration
1	64	40	62
2	55	48	45
2*	50	43	39
3	13	6	8
4	8	4	4

*excluding the R&D industry.
Note: based on the Statistics Denmark's R&D statistics, which is based on a representative sample of around 4,000 companies, see table 4.1

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Innovation in companies that contribute to core R&D competences

A larger share of the companies in group 1 have generated product, process, organizational and marketing innovations compared to companies that have only contributed to core R&D competences but are not located in an industry with a business stronghold (group 2) (see table 4.4). Being located in an industry with a business stronghold may the companies more innovative. An underlying factor could be that a larger fraction of companies in an industry with a business stronghold have their own R&D department, thus explaining the higher degree of innovation.

4.4 Employment in R&D active firms by research fields

This section gives an overview of the relative size (in terms of employment) of the research fields. Some research fields are characterized by firms that patent and other by firms that publish.

In sections 4.1 - 4.3, companies that contribute to core R&D competences and/or are located in industries that have a business stronghold were analysed. This section is expanded to include companies that have generated patents and/or publications during the period of study within research areas that have a below-average impact on the international research front, i.e. *potential* core R&D competences. This gives a more comprehensive picture of the research status within each research field. Furthermore, it enables a comparison of the size of each research field with respect to number of employees, revenue, value added and exports.

Figures 4.4 and 4.5 show how many employees (full time equivalents) companies that patent/publish employ within each research field. If a company patents/publishes in more than one research field, its employees have been counted in both research fields. The figure is furthermore divided according to whether or not the companies have patented/published in a research area where Denmark has a core competence in R&D. Some companies will have patented/published both in areas where Danish firms hold core R&D competences and in areas where they do not. The figures shed light on how companies that contribute to core R&D competences (or to potential core competences) are distributed across research fields. The research field *Chemistry* is for example driven solely by companies that have an above-average impact on the international research front, while *Information technology* is at least partly driven by companies that contribute to research areas that are potential core competences.

The figures also highlight the different patenting/publishing behaviour within each research field. *Civil & Mechanical engineering* is the largest research field for patents; large firms in the field are also publishing. *Environmental* and *General Medicine* are large within publishing but are fields with less patenting activity. On the other hand "Instruments" are large within patenting but have less publicizing activities. For the economic characteristics of each field, see tables 4.5 and 4.6

TABLE 4.4

Innovation type (percent of firms)

Group	Group	innovation total	product	process	organization	marked
Core R&D comp. & business stronghold	1	90	79	50	71	52
Core R&D comp. only	2	72	55	44	53	41
Core R&D comp. Only *	2*	79	64	50	62	47
Business stronghold only	3	60	33	29	40	33
no core comp. & no business stronghold	4	51	25	26	35	29

*excluding the R&D industry.

Note: based on the Statistics Denmark's R&D statistics, which is based on a representative sample of around 4,000 companies, see table 4.1

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FIGURE 4.4
Number of employees in companies that patent in areas with or without a core R&D competence

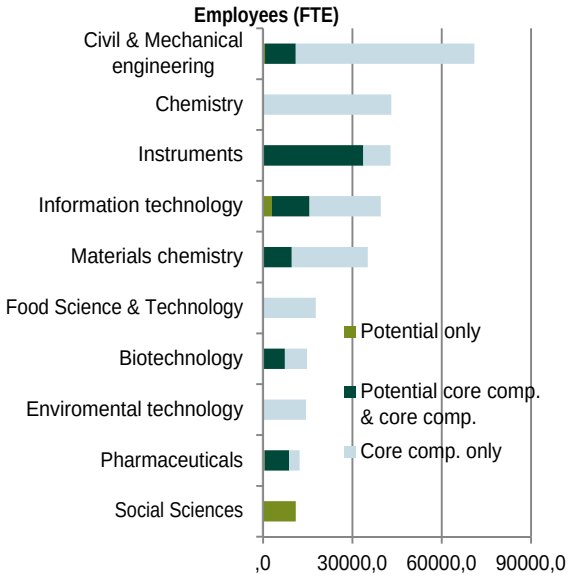

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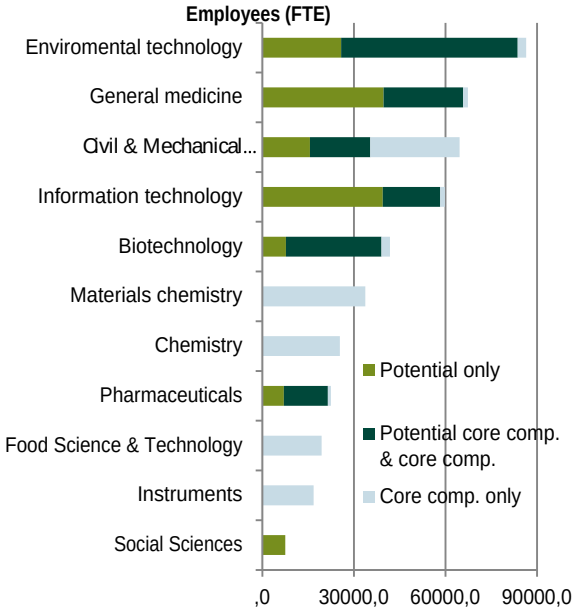
FIGURE 4.5
Number of employees in companies that publish in areas with or without a core R&D competence



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Tables 4.5 and 4.6 show the contribution from companies that patent/publish with respect to employment, revenue, value added, export and import within each research field. The tables cover both companies that do and do not contribute to core R&D competences. If companies patent/publish in multiple research fields, their activities are counted in each field.

4.5 Average impact research field level

Some research fields are more diverse than others

Each research field covers multiple patents/publications. To get an idea of the composition of each research field with regard to competences, figures 4.6 and 4.7 shows the average impact of the patens/publications within the research field. Furthermore, they also show the minimum and maximum impact to give a picture of the distribution within each field. *Chemistry* is for example characterized by having an above-average impact for both patents and publications and a closer distance between minimum and maximum impact compared to e.g. *Information technology*. A closer distribution can reflect a more narrow definition of the research field (i.e. the competences are more alike) compared to research fields with a wider distribution (i.e. more diverse competences)

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TABLE 4.5

Contribution to the Danish economy from companies that patent

Research fields	Firms	Employees	Revenue	Value added	Export	Import
Patents	#	#		Million DKK		
Civil & Mechanical engineering	302	70,995	155,073	55,710	82,684	29,192
Instruments	164	42,814	86,768	35,892	46,450	14,839
Information technology	129	39,548	58,512	25,201	32,209	10,004
Chemistry	96	43,090	64,821	23,773	33,272	12,371
Materials chemistry	92	35,178	68,859	26,530	36,250	13,189
Biotechnology	83	14,754	40,559	11,553	19,074	8,246
Pharmaceuticals	78	12,268	29,165	9,421	19,155	5,771
Environmental technology	47	14,411	30,988	10,501	21,859	7,277
Food Science & Technology	45	17,683	47,248	12,401	32,724	7,138
Social Sciences	42	11,007	23,570	8,834	12,710	4,706

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TABLE 4.6

Contribution to the Danish economy from companies that publish

Research fields	Firms	Employees	Revenue	Value added	Export	Import
Publications	#	#		Million DKK		
Environmental technology	230	86,446	215,333	75,382	105,508	36,760
General medicine	168	67,339	179,853	63,706	84,606	26,254
Civil & Mechanical engineering	104	64,634	149,429	58,192	75,589	27,859
Information technology	108	59,792	148,868	55,536	81,420	27,597
Biotechnology	91	41,807	108,311	39,392	50,976	14,364
Materials chemistry	42	33,710	82,043	32,036	38,796	13,008
Chemistry	19	25,400	66,154	25,116	27,623	14,451
Pharmaceuticals	34	22,428	54,536	25,552	24,528	7,836
Food Science & Technology	35	19,405	56,115	17,226	29,427	7,138
Instruments	17	16,785	39,046	17,478	14,590	6,223
Social Sciences	15	7,521	17,652	6,308	7,659	4,020

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FIGURE 4.6

Average patent impact in the research field

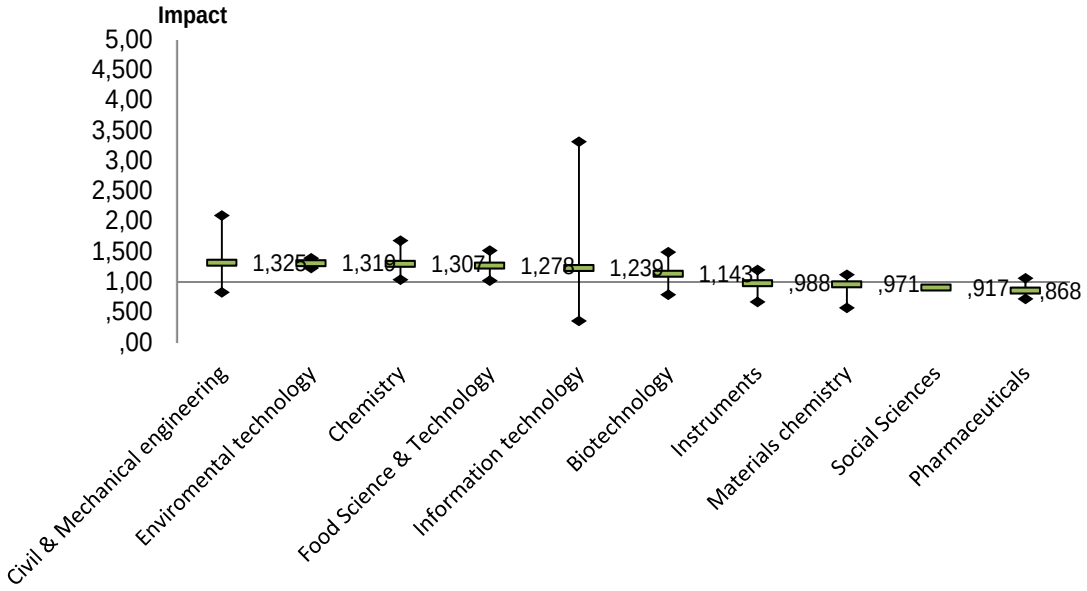

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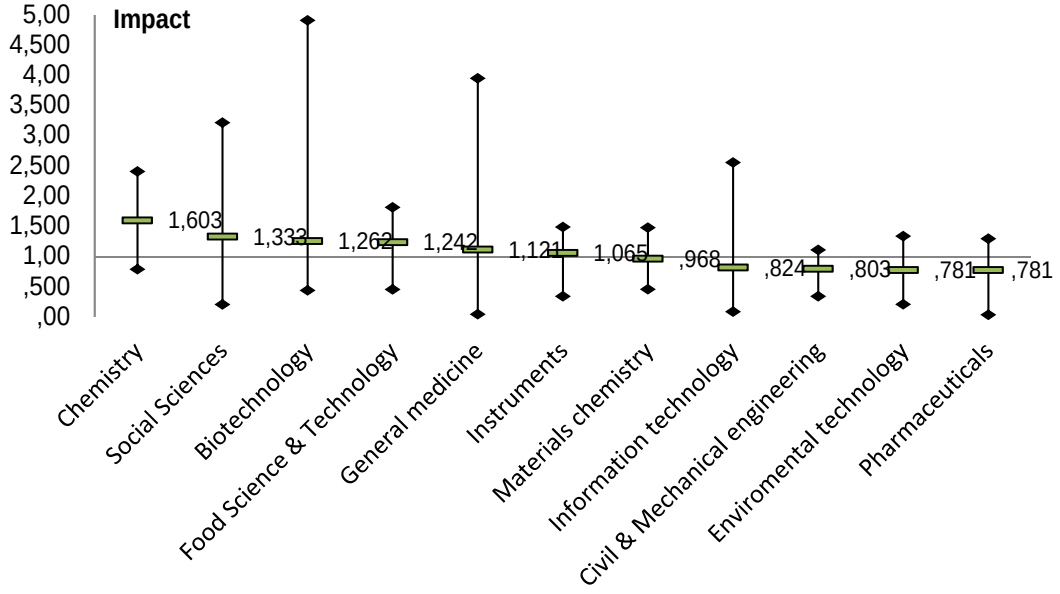
FIGURE 4.7

Average publication impact in the research field.



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4.6 Average impact industry sector level

To get an idea of different industries' impact on the research frontier, figures 4.8 and 4.9 show the industries' average impact for both research areas that are and are not core R&D competences.

It is important to note that competences are not identified at the industry level but on the level of the competences. It is not possible to extract how much each company (and thereby industry) contributes to the impact of the given competence.

The average impact for the industry is calculated as a simple average of the impact of the different core competences that companies in the industry contribute to. The average impact is however not weighted according to volume, i.e. to the number of patents or publications behind the core competence.

In the fictive industry X, companies in the industry contribute to six patent based core research competences with different relative impacts, which gives the industry an average impact of 1.05 (see table 4.7).

There is no meaningful way to combine the impact for patent based and publication based core competences in one measure. Industry impact is therefore treated separately for patents and publications in figures 4.8 and 4.9, respectively. Industries with less than four companies contributing to a competence are left out of the figures due to confidentiality issues. For the patent based core competences, all the industries but one have an average impact above one.

TABLE 4.7

Illustration of how average impact is calculated for a fictitious industry X

Patent based core competences	Impact
Pat A	0.92
Pat B	1.07
Pat C	1.09
Pat D	1.10
Pat E	1.16
Pat F	0.96
Average impact for the industry	**1.05**

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One must be cautious in the interpretation of the figures. The industry with the highest impact within publications is the *Wood, paper and printing* industry. This score is however obtained on the basis of only two competences, whereas the impact score of the *Pharmaceutical* industry is based on 69 competences.

FIGURE 4.8

Average patent impact by industry

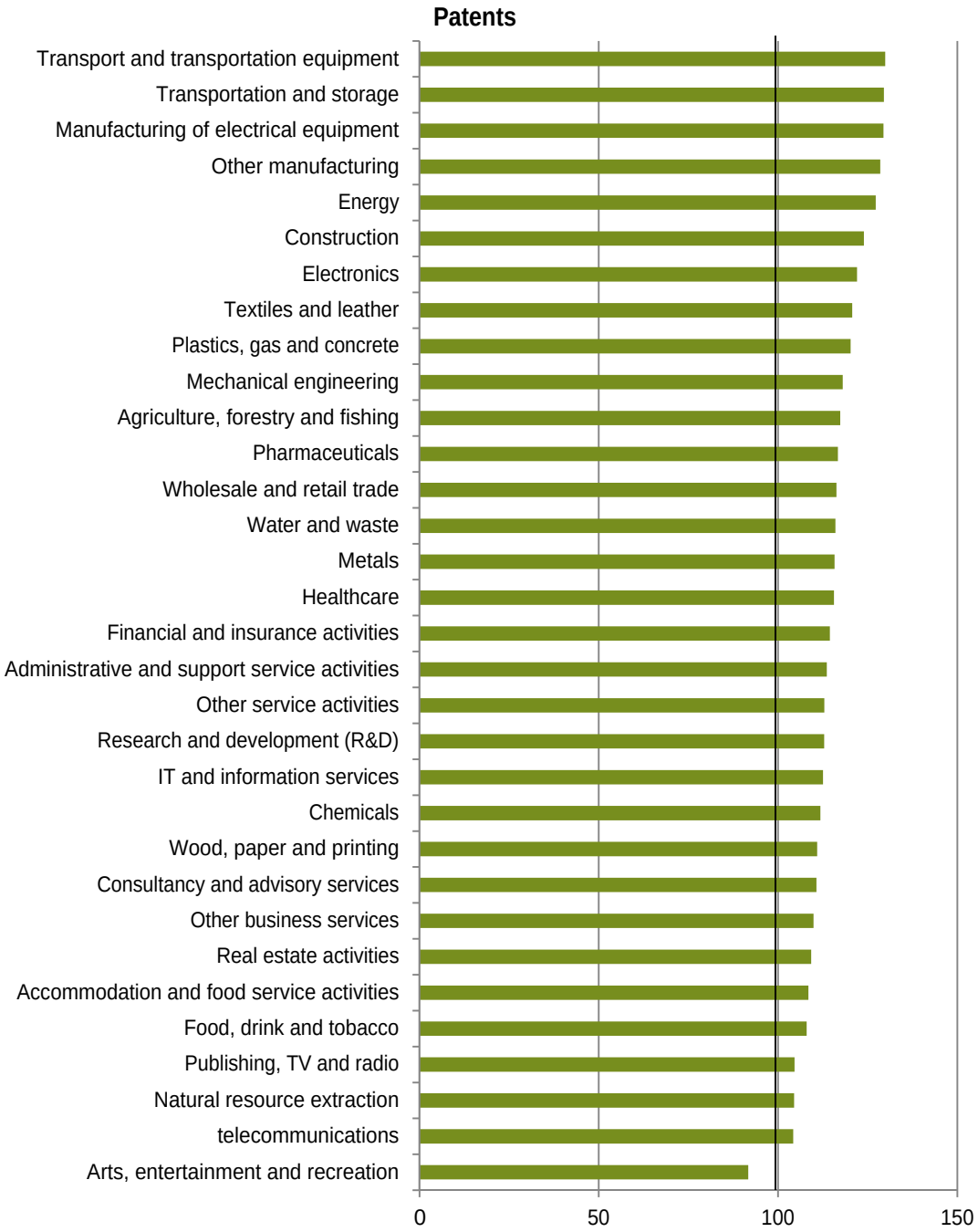

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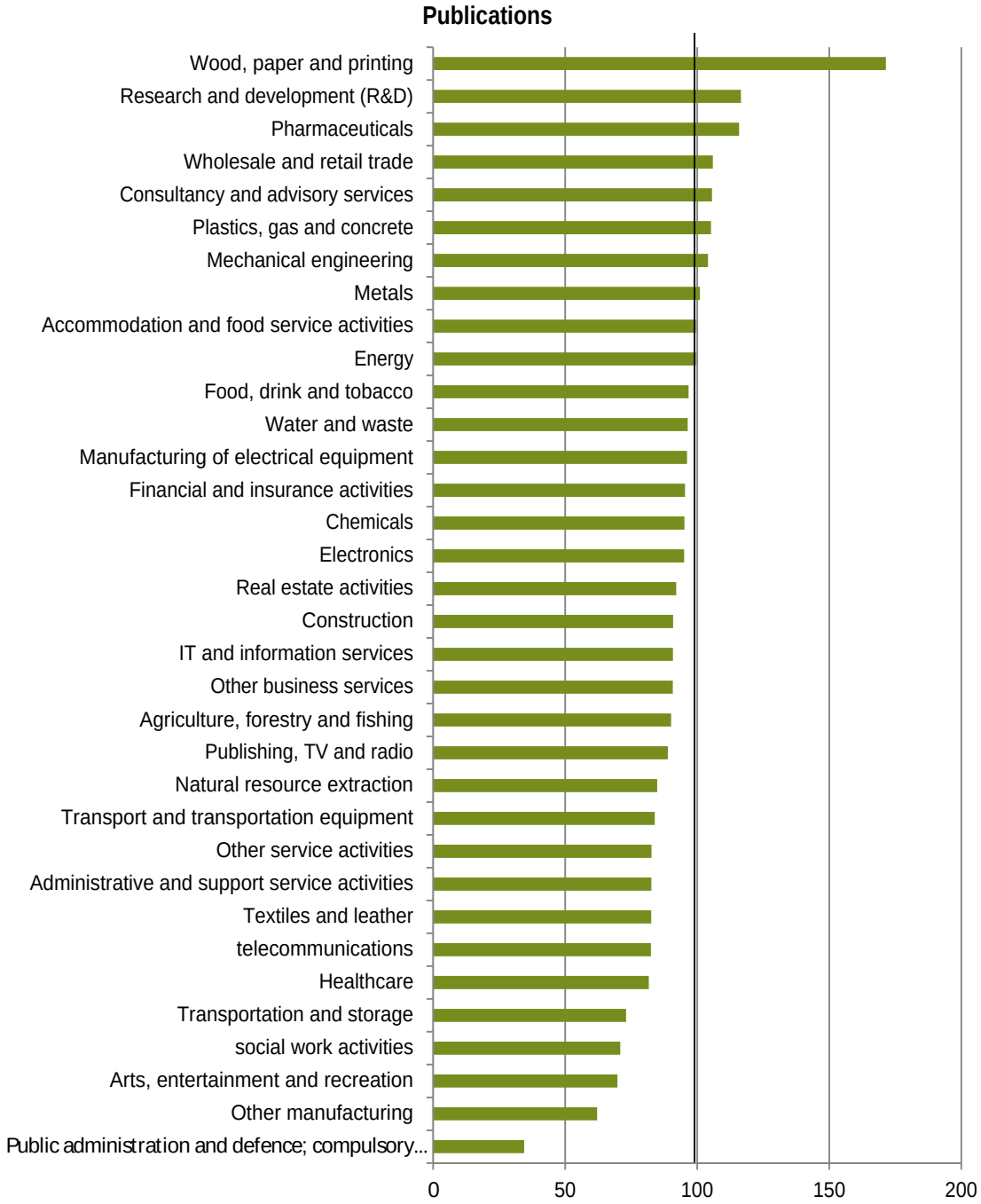
FIGURE 4.9

Average publications impact by industry



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5 Methodology

This chapter briefly describes the method used in the analyses summarised in this report. The methods were selected and developed in dialogue with the Danish Agency for Science, Technology and Innovation.

5.1 Guiding principles in the definition and identification of core R&D competences

The following guiding principles were applied in the development of the methodology.

1. Core competences should be identified using a systematic, "bottom up"-approach.

National R&D competences are often identified through a "top down"-approach whereby experts in a range of fields are asked to identify key national research areas. This approach is dependent on the knowledge and objectivity of the selected experts.

To ensure a comprehensive and objective identification of core competences in Danish private sector R&D, we apply a "bottom up"-approach that systematically assesses the relative international impact of a broad range of research areas.

To allow for a systematic identification of core competences in Danish private sector R&D, we use data on all patents and scientific publications by Danish firms during the period 2000-2011, both years included.

2. Core competences are defined as research areas in which firms have an above-average impact on the international research front.

In other words, the mapping should identify research areas in which Danish firms make a significant difference in the international production of knowledge.

The analysis should capture both large research areas and smaller niche research areas in Danish industry. The defining aspect of a core competence is therefore not the absolute size of a given research area, but its *relative scientific impact* compared to international research.

Thus, the impact of Danish firms' research is compared to the impact of international public and private sector research in the same research areas.[7]

3. Core competences should be in established research areas, i.e. areas in which Danish industry has exhibited an above-average impact over a significant period of time.

The mapping will provide inputs to the development and implementation of a national innovation strategy aimed at exploiting and expanding existing national strengths in research and industry. A number of research areas will be selected and form the basis for dedicated efforts to boost innovation. To be effective, such efforts must build on established core competences, that is, on existing R&D activities, actors and achievements.

Core competences are therefore identified as research areas in which Danish firms have had an above-average impact on the international front when examined *over the last decade*. In other words, for a private sector research area to constitute a core competence, its average impact must have been higher than the average impact of international (public and private sector) research in

[7] By comparing like with like, this approach takes into consideration differences in scientific impact across research fields.

the same research area when calculated over the entire period of study, i.e. from 2000 to 2011.

5.2 Data

Core competences are identified through a systematic analysis of publications and patents by Danish firms during the period 2000 to 2011 (both years included).

By patents, we actually refer to *patent applications* (and not necessarily granted patents), although we use the terms "patent" and "patent application" interchangeably in this report. Patent applications are often used as indicators for firms' R&D activities, because they are used to protect novel inventions and discoveries by firms. Patents may be based on firms' in-house research or on research undertaken in collaboration with other firms and/or public institutions.

By publications, we refer to *publications in leading international peer-reviewed scientific journals*. Scientific publications are more commonly used as indicators for R&D activities by academic researchers. Increasingly, they are also used as proxies for firms' research activities, including in-house and collaborative research.

Firms publish articles for a number of reasons, including for instance to signal their R&D activities, to prevent patenting ("defensive publishing"), to provide incentives for the researchers that they have employed, and because publishing is often (though not always) an outcome of R&D collaboration with public scientists.

Collection of patent data

- A list of approximately 3,095 Danish firms that could potentially have applied for patents was generated using desk research.
- A search for patent applications assigned to Danish firms was conducted based on individual patent searches for each of the 3,095 firms.
- Subsequently, data on citations to all the patent applications identified was gathered.
- A total of 13,696 patent applications assigned to 803 Danish firms were identified.

Source of data:

The list of 3,095 Danish firms that could potentially have applied for a patent was established based on the following inputs:

- *List of firms participating in Danish and EU research and innovation programs (from DAMVAD's proprietary Collaboration Database)*
- *List of firms that have co-authored publications with key Danish universities over the past decade (from DAMVAD's proprietary Research Database)*
- *Lists of firms that have engaged in research collaboration with selected authorized technological services institutes (GTS), provided by DASTI*
- *Lists of firms involved in Danish innovation networks, provided by DASTI..*

Patents were gathered from Thomson Reuters' Derwent World Patents Index. Citation data was gathered from the EPO-OECD patent citation database (June 2010 version).

Collection of publication data

- Publications that were authored or co-authored by employees from Danish firms were identified through a search for publications with author affiliations with a Danish company form and address. Supplementary searches were undertaken for each of the firms thus identified (including for different variations of the company name).
- A total of 15,157 publications were identified for 650 firms.

Source of data: *Publications were gathered from Thomson Reuters' Web of Science database.*

5.3 Approach

Core competences in Danish private sector R&D are defined as areas in which publications or patents by Danish firms have an above-average impact compared to publications or patents, respectively, in the same research area from other countries.

Impact refers to the scientific impact of a publication or patent, as indicated by the number of times that it is cited by other publications or patents, respectively.[8]

Publications and patents are categorised under specific **research areas.** In total, 278 patent based research areas and 208 publication based research areas were examined in the study.

[8] The analysis of impact is corrected for self-citations.

Moreover, it is important to note that citation mechanisms differ for publications and patents. In publications, citations are made by the authors of publications and refer to the previous work that their research builds on; citations may also be used to position a publication against the existing scientific literature. Such citations can be influenced by a number of factors, including for instance researchers' social networks and thereby their frames of reference. In patents, however, citations to prior patents are typically assigned by an external examiner in a patent office; these citations are intended to indicate relevant prior art and primarily influenced by the examiners and their expert knowledge of the research area and topic of the patent.

In spite of these differences, for both publications and patents, citations can be used an indicator for the extent to which publications and patents are referenced and built upon in subsequent work and therefore provide a proxy for their impact on the international research front.

Finally, the assessment of the impact of company patents only includes patents filed with the European Patent Office (EPO) and the World Intellectual Property Organization (WIPO). The study thus excludes e.g. U.S. patents. This approach is generally accepted as the standard procedure for this type of patent analysis in the academic literature because of inconsistencies in patent examiners' procedures for assigning patent citations within the different patenting systems.

Research areas were identified:

- For publications, based on Thomson Reuters' Web of Science subject areas, which are assigned to scientific journals (and thus, by extension) to scientific publications.
- For patents, based on International Patent Classification (IPC) codes, which are used for the classification of patents according to the areas of technology to which they pertain.

Identification of core competences: A research area was identified as a core competence

- If the research area is based on at least 10 publications or 10 patent by Danish firms during the period of study (i.e. from 2000 to 2011, both years included).[9]
- If the impact of publications or patents in the research area by Danish firms was, on average over the past decade, higher than the average impact of international research. For publications, this refers to research conducted within the OECD countries; for patents, international research refers to patents applied for worldwide.[10]

[9] The minimum number of publications and patents that could constitute a core competence was set low (i.e. at 10) for two reasons: (1) to allow for the identification of niche research areas, which may be small in volume but still make a significant contribution to international research, and (2) in consideration of the fact that some research areas generate fewer publications or patents than others and might therefore be disadvantaged in this analysis. E.g. the social sciences generate far fewer publications per researcher than e.g. the natural sciences.

[10] Please note that Danish firms' publications were compared to publications from other OECD countries to ensure the relevance of the data used in the comparison. The impact of Danish patents was assessed against patents from all countries.

5.4 Link to register data and business strongholds

As stated in chapter 4, this part of the analysis draws on register data on Danish firms and on the list of Danish business strongholds (in Danish, "erhvervsmæssige styrkepositioner") identified by the Ministry of Business and Growth.

Both core competences in R&D and business strongholds were linked to every company in Denmark based on the following categorisation:

- A company is linked to a core R&D competence if it publishes or patents within a research area, which is identified as a core competence in R&D (i.e. has a relative international impact higher than 1 and is based on more than 10 publications or patents).
- A company is linked to a business stronghold if its economic activities take place within an industry, which is identified as a business stronghold.

Core competences in R&D and business strongholds have been linked by company registration number to a population consisting of all companies in Denmark in 2009 (133.315) (see table 4.1). This was done through researcher access to register data from Statistics Denmark. The company registration number was used to combine information from the firm register, education register, accounting register, and R&D register.

The use of the link between the company registration number and the industry sectors is crucial for the present analysis and hence this, relies on the quality and precision of the classification made. The classification of firms in to sectors still persist some challenges for the analysis. And the inconsistency of the classification could lead to misin-

terpretation of connect between core competences and industry sectors. Despite the difficulties this could cause the results presented in the present report is still reliable and forms a valid point of departure for further analysis as described and outlined in sector 5.1.

The R&D register is based on a survey of around 4,000 representative companies each year. Large firms are given greater weight in the survey. Though just 3 percent of all firms are covered in the survey, more than 50 percent of the companies with a core competence in R&D are covered because of their relative large size (see table 5.1).

TABLE 5.1

Number of companies

Group	All	R&D sample	Covered (percent)
1	67	42	63
2	437	229	52
2*	341	155	45
3	20.411	328	2
4	112.400	3.836	3
All	133.315	4.435	3

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* excluding the R&D industry

Note: The R&D statistics in Denmark is based on a representative sample of around 4,000 companies. The companies in groups 1 and 2 are relatively well represented because of their larger size.

5.5 Limitations and uses of the findings

On the mapping of core R&D competences

The mapping of core competences and business strongholds in Danish private sector R&D presented in this report is intended as a **point of departure** for (1) the identification of existing strengths in Danish research and industry, and (2) an assessment of how these strengths should be maintained and developed in the coming years.

The analysis presented in this report is based on the premise that positions of strength in research and industry should not be addressed with a "one size fits all"-model. Rather, insight into the particular potential, challenges and needs of each position of strength should be used to develop a customised plan of action for boosting innovation within that position of strength.

This report is intended to support the identification of Danish strengths in research and industry – and the development of a national innovation strategy to expand these strengths – in two ways:

- By pointing to international research areas where Danish firms have exhibited an overall strong performance over the past decade and which may therefore constitute or contribute to overall positions of strength in Danish research and industry.
- By providing access to rich empirical data on these research areas that can be analysed further as part of the development and implementation of the national innovation strategy.

The data collected in connection with this mapping provides several opportunities for further analysis of data, including for instance:

- Analyses of how Danish firms' involvement and performance in selected research areas have developed over time
- Analysis of the degree of collaboration between Danish firms
- Analysis of the Danish public sector institutions that the firms collaborate with and the extent to which they collaborate.
- Analysis of Danish firms' collaboration with international research institutions and companies.

Such analyses could provide important insight into the particular strengths and weaknesses of selected core competences in private sector R&D.

On the use of register data

The newest Danish register data from 2009 is used. 504 out of the 678 companies could be identified in Statistics Denmark's Firm statistics in 2009. The remaining companies are either established in the period 2009-2012 or have changed CVR number since 2009.

Limitations of the methods

Some limitations of the method – and therefore the results – should be noted. First, the method is biased toward companies, research areas and industries that publish and/or patent their R&D results. For example, companies in certain industries (e.g. biotechnology) are both prolific publishers and patent holders. Moreover, large research-intensive firms are likely to have greater resources to fund publishing and patenting activity. Such industries and firms are therefore more likely to appear in the results of this analysis.

Meanwhile, a large part of research and innovation in industry is neither patented nor published. Many firms, particularly small and medium-sized enterprises, develop new products, services and processes without taking out patents or publishing their results. This is especially the case in low-tech industries, for instance consultancy and advisory services. This analysis can only capture private sector R&D core competences that can be identified through a systematic analysis of publication and patent data.

Second, because the method applied defines core competences based on the *relative* rather than absolute impact of a research area in private sector R&D, a core competence identified in this mapping can be based on anywhere from 10 to hundreds of publications or patents. This method was selected to reduce the bias toward research areas characterised by a large degree of patenting and/or publishing and to allow for the identification of strong "niches" in Danish firms' R&D. However, in the further, more detailed analysis of the core competences presented in this report, it is important to consider the volume of patents and/or publications on which they are based.

Finally, the method allows for significantly better coverage of research in the natural and technical sciences than in the social sciences and humanities. Research in the latter sciences is generally not patented; moreover, the natural and technical sciences generate far more publications than the social sciences and humanities. This is especially true of firms' publications. For example, a pharmaceutical firm is more likely to publish the results of a drug discovery project than a consulting firm is likely to publish the results of a change management process in a client company. Thus, the method used to identify core competences in private sector R&D is likely to underestimate firms' research in the social sciences and humanities.[11]

[11] It should be noted that the analysis reported here actually revealed a number of core competences in social sciences and humanities research. However, the majority of these were excluded because they were based on less than 10 publications or patents by Danish firms over the past decade.

Appendix 1

TABLE AP1.1

All 102 core competences in Danish private sector R&D, organized by research field

Research field	Patent based core competences	Publication based core competences
Chemistry	Organic fine chemistry Chemical engineering Macromolecular chemistry, polymers Macromolecular chemistry, polymers / Organic fine chemistry Macromolecular chemistry, polymers / Other special machines Macromolecular chemistry, polymers / Surface technology, coating	Chemistry / Engineering
Materials chemistry	Materials, metallurgy Materials, metallurgy / Surface technology, coating Surface technology, coating Basic materials chemistry Basic materials chemistry / Macromolecular chemistry, polymers Basic materials chemistry / Organic fine chemistry	Physics / Science & Technology - Other Topics / Materials Science Chemistry / Science & Technology - Other Topics / Materials Science Materials Science / Metallurgy & Metallurgical Engineering Electrochemistry / Materials Science
Biotechnology	Biotechnology Biotechnology / Basic materials chemistry Biotechnology / Food chemistry	Biochemistry Molecular Biology / Life Sciences & Biomedicine - Other Topics / Cell Biology Mycology Cell Biology / Oncology Biochemistry Molecular Biology / Biophysics Virology Biotechnology applied microbiology / Microbiology Biophysics
Pharmaceuticals	Pharmaceuticals Organic fine chemistry / Pharmaceuticals	Pharmacology & Pharmacy / Psychiatry Neurosciences & Neurology / Pharmacology & Pharmacy Neurosciences & Neurology / Physiology
General medicine	-	Integrative & Complementary Medicine Respiratory System Endocrinology & Metabolism / Physiology Allergy Cardiovascular System & Cardiology / Neurosciences & Neurology Immunology / Infectious Diseases Genetics & Heredity / Research & Experimental Medicine Geriatrics & Gerontology / Neurosciences & Neurology Reproductive Biology Otorhinolaryngology Nursing Behavioral Sciences Surgery / Transplantation General & Internal Medicine / Research & Experimental Medicine Transplantation Anesthesiology Rehabilitation Orthopedics / Rheumatology Medical Laboratory Technology

TABLE AP1.1 (CONTINUED)

All 102 core competences in Danish private sector R&D, organized by research field

Research field	Core Competences (patents)	Core Competences (publications)
Food science & technology	Food chemistry Food chemistry / Pharmaceuticals	Health Care Sciences & Services / Public, Environmental & Occupational Health Veterinary Sciences / Zoology Nutrition & Dietetics / Food Science & Technology Biotechnology applied microbiology / Food Science & Technology Food Science & Technology / Microbiology Endocrinology & Metabolism / Nutrition & Dietetics
Enviromental technology)	Chemical engineering / Environmental technology Environmental technology	Fisheries Engineering / Environmental Sciences & Ecology / Water Resources Zoology Entomology Agriculture
Instruments	Medical technology Optics	Physics / Science & Technology - Other Topics / Optics Microscopy Engineering / Optics Optics / Physics
Civil & mechanical engineering	Civil engineering Engines, pumps, turbines Engines, pumps, turbines / Mechanical elements Handling Machine tools Mechanical elements Other special machines Other special machines / Surface technology, coating Thermal processes and apparatus Transport Electrical machinery, apparatus, energy / Mechanical elements Electrical machinery, apparatus, energy Electrical machinery, apparatus, energy / Semiconductors	Engineering / Instruments & Instrumentation Engineering / Geology Mineralogy Physical Geography Energy & Fuels / Engineering
Information Technology	Audio-visual technology Audio-visual technology / Computer technology Audio-visual technology / Electrical machinery, apparatus, energy Audio-visual technology / Semiconductors Computer technology Computer technology / Control Computer technology / IT methods for management Digital communication Digital communication / Telecommunications Computer technology / Medical technology	Medical Informatics Mathematical & computational Biology

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Appendix 2

This appendix lists the top five core R&D competences that individual industry sectors contribute to.

The top five core competences are the five core competences that firms from a given industry contribute most to, as indicated by the volume of publications or patents behind the core competence.

For each industry, the tables below present:

i) the total number of core competences that firms in the industry contribute to

ii) the top five core competences ranked by the ratio of patents (or publications) behind each core competence that are assigned to firms from that industry, divided by the total number of patents (or publications) behind the given core competence

iii) the number of firms from this industry that have contributed to the given core competences.

As an example, table AP2.1 below shows that firms from the sector other services contribute to a number of core competences in private sector R&D. The core competence that the industry has the highest contribution to are “Pat 27”, in computer technology / IT methods for management. One firm from the industry has contributed to this core competence, with a total of 8% of the patents behind the core competence.

Section A of this appendix presents various industries’ contribution to *patent* based core competences, while section B presents industries’ contribution to *publication* based core competences.

A. Danish private sector R&D core competences based on patents

TABLE AP2.1: SECTOR - OTHER SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pat 27	Computer technology / IT methods for management	1	8%
	Pat 33	Computer technology	1	7%
	Pat 5	Computer technology / Medical technology	1	6%
	Pat 22	Medical technology	2	3%

TABLE A2: SECTOR - CONSTRUCTION

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
5	Pat 4	Transport	1	12%
	Pat 24	Civil engineering	2	11%
	Pat 14	Other special machines / Surface technology, coating	1	4%
	Pat 37	Electrical machinery, apparatus, energy	2	4%
	Pat 32	Materials, metallurgy	1	2%

TABLE AP2.3: ELECTRONICS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
37	Pat 38	Audio-visual technology	10	96%
	Pat 33	Computer technology	9	69%
	Pub 44	Otorhinolaryngology	4	65%
	Pat 18	Audio-visual technology / Computer technology	4	63%
	Pat 1	Audio-visual technology / Electrical machinery, apparatus, energy	9	60%

TABLE AP2.4: ENERGY

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pat 32	Materials, metallurgy	1	1%
	Pat 37	Electrical machinery, apparatus, energy	1	1%
	Pat 29	Engines, pumps, turbines	2	1%
	Pat 40	Biotechnology	1	0%

TABLE AP2.5: PUBLISHING, TV AND RADIO

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
3	Pat 33	Computer technology	3	13%
	Pat 42	Optics	1	3%
	Pat 37	Electrical machinery, apparatus, energy	1	0%

TABLE AP2.6 RESEARCH AND DEVELOPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
27	Pat 39	Organic fine chemistry	12	98%
	Pat 12	Handling	3	91%
	Pat 26	Organic fine chemistry / Pharmaceuticals	10	48%
	Pat 11	Other special machines	8	48%
	Pat 40	Biotechnology	50	42%

TABLE AP2.7: MANUFACTURING OF ELECTRICAL EQUIPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
20	Pat 42	Optics	5	93%
	Pat 38	Audio-visual technology	6	58%
	Pat 37	Electrical machinery, apparatus, energy	14	49%
	Pat 1	Audio-visual technology / Electrical ma-	2	30%

		chinery, apparatus, energy		
	Pat 33	Computer technology	5	20%

TABLE AP2.8: FOOD, DRINKS AND TOBACCO

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
19	Pat 23	Macromolecular chemistry, polymers	1	59%
	Pat 9	Food chemistry	12	42%
	Pat 43	Food chemistry / Pharmaceuticals	3	42%
	Pat 6	Macromolecular chemistry, polymers / Organic fine chemistry	1	31%
	Pat 28	Basic materials chemistry	2	10%

TABLE AP2.9: IT AND INFORMATION SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
17	Pat 33	Computer technology	20	44%
	Pat 27	Computer technology / IT methods for management	4	31%
	Pat 38	Audio-visual technology	5	31%
	Pat 12	Handling	3	26%
	Pat 8	Computer technology / Control	2	18%

TABLE AP2.10: CHEMICALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
22	Pat 28	Basic materials chemistry	5	93%
	Pat 10	Biotechnology / Basic materials chemistry	1	74%
	Pat 9	Food chemistry	1	73%
	Pat 40	Biotechnology	3	69%
	Pat 45	Basic materials chemistry / Organic fine chemistry	2	69%

TABLE AP2.11: AGRICULTURE, FORESTRY AND FISHERY

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pat 11	Other special machines	3	5%
	Pat 21	Biotechnology / Food chemistry	1	1%
	Pat 28	Basic materials chemistry	1	1%
	Pat 40	Biotechnology	1	1%

TABLE AP2.12: MECHANI-CAL ENGINEERING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
25	Pat 46	Mechanical elements	14	99%
	Pat 4	Transport	7	85%
	Pat 29	Engines, pumps, turbines	18	84%
	Pat 32	Materials, metallurgy	6	60%
	Pat 16	Environmental technology	8	49%

TABLE AP2.13: PHARMACEUTICALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
26	Pat 39	Organic fine chemistry	6	98%
	Pat 22	Medical technology	6	58%
	Pat 8	Computer technology / Control	1	55%
	Pat 33	Computer technology	2	46%
	Pat 26	Organic fine chemistry / Pharmaceuticals	5	43%

TABLE AP2.14: METALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
12	Pat 44	Surface technology, coating	6	67%
	Pat 12	Handling	4	23%
	Pat 20	Chemical engineering / Environmental technology	2	20%
	Pat 16	Environmental technology	2	19%
	Pat 34	Machine tools	5	12%

TABLE AP2.15: OTHER MANUFACTURING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
22	Pat 19	Thermal processes and apparatus	1	96%
	Pat 46	Mechanical elements	1	79%
	Pat 37	Electrical machinery, apparatus, energy	4	73%
	Pat 4	Transport	3	64%
	Pat 44	Surface technology, coating	2	61%

TABLE AP2.16: PLASTICS, GLAS AND CONCRETE

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
29	Pat 12	Handling	11	69%
	Pat 24	Civil engineering	12	51%
	Pat 7	Macromolecular chemistry, polymers / Other special machines	2	46%
	Pat 23	Macromolecular chemistry, polymers	3	41%
	Pat 41	Basic materials chemistry / Macromolecular chemistry, polymers	4	39%

TABLE AP2.17: OTHER BUSINESS SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
13	Pat 33	Computer technology	7	24%
	Pat 27	Computer technology / IT methods for management	2	23%
	Pat 4	Transport	4	9%
	Pat 8	Computer technology / Control	1	9%
	Pat 24	Civil engineering	3	6%

TABLE AP2.18: CONSULTANCY AND ADVISORY SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
27	Pat 12	Handling	6	83%
	Pat 32	Materials, metallurgy	5	79%
	Pat 31	Chemical engineering	12	67%
	Pat 16	Environmental technology	15	65%
	Pat 45	Basic materials chemistry / Organic fine chemistry	2	52%

TABLE AP2.19: NATRUAL RESOURCE EXTRACTION

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
2	Pat 24	Civil engineering	2	33%
	Pat 46	Mechanical elements	1	4%

TABLE AP2.20: HEALTHCARE

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pat 5	Computer technology / Medical technology	1	3%
	Pat 36	Pharmaceuticals	1	2%
	Pat 39	Organic fine chemistry	1	1%
	Pat 26	Organic fine chemistry / Pharmaceuticals	1	0%

TABLE AP2.21: TEXTILES AND LEATHER

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
2	Pat 4	Transport	2	94%
	Pat 14	Other special machines / Surface technology, coating	1	4%

TABLE AP2.22: TRANSPORT AND TRANSPOR-TATION EQUIPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pat 24	Civil engineering	1	6%
	Pat 14	Other special machines / Surface technology, coating	1	4%
	Pat 10	Biotechnology / Basic materials chemistry	1	1%
	Pat 40	Biotechnology	1	0%

TABLE AP2.23: WOOD, PAPER AND PRINTING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
2	Pat 11	Other special machines	3	11%
	Pat 37	Electrical machinery, apparatus, energy	1	2%

TABLE AP2.24: WATER AMD WASTE

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
10	Pat 37	Electrical machinery, apparatus, energy	1	85%
	Pat 29	Engines, pumps, turbines	1	56%
	Pat 19	Thermal processes and apparatus	1	35%
	Pat 31	Chemical engineering	2	15%
	Pat 2	Electrical machinery, apparatus, energy / Semiconductors	1	10%

B. Danish private sector R&D core competences based on publications

TABEL AP2.25: ELECTRONICS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
22	Pub 44	Otorhinolaryngology	5	65%
	Pub 27	Engineering; Optics;	2	22%
	Pub 42	Reproductive Biology	1	17%
	Pub 36	Medical Informatics	1	13%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	3	10%

TABEL AP2.26: ENERGY

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
8	Pub 34	Materials Science; Metallurgy & Metallurgical Engineering;	2	24%
	Pub 41	Energy & Fuels; Engineering;	3	16%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	1	5%
	Pub 45	Engineering; Geology;	1	3%
	Pub 4	Chemistry; Engineering;	2	3%

TABEL AP2.27: PUBLISHING, TV AND RADIO

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
5	Pub 14	Physics; Science & Technology - Other Topics; Optics	1	3%
	Pub 16	Physics; Science & Technology - Other Topics; Materials Science	1	3%
	Pub 43	Endocrinology & Metabolism; Nutrition & Dietetics;	1	2%
	Pub 9	Rehabilitation	1	1%
	Pub 39	Engineering; Instruments & Instrumentation;	1	1%

TABEL AP2.28: RESEARCH AND DEVELOPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
53	Pub 17	Mycology	3	68%
	Pub 37	Neurosciences & Neurology; Pharmacology & Pharmacy;	3	46%
	Pub 42	Reproductive Biology	7	45%
	Pub 33	Genetics & Heredity; Research & Experimental Medicine;	7	44%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	9	43%

TABEL AP2.29: MANUFACTURING OF ELECTRICAL EQUIPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
5	Pub 27	Engineering; Optics;	1	13%
	Pub 14	Physics; Science & Technology - Other Topics; Optics	1	7%
	Pub 39	Engineering; Instruments & Instrumentation;	3	4%
	Pub 28	Optics; Physics;	2	4%
	Pub 41	Energy & Fuels; Engineering;	1	0%

TABEL AP2.30: FOOD, DRINK AND TOBACCO

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
17	Pub 22	Fisheries	4	34%
	Pub 24	Nutrition & Dietetics; Food Science & Technology;	5	27%
	Pub 46	Food Science & Technology; Microbiology;	2	22%
	Pub 53	Agriculture	9	18%
	Pub 13	Integrative & Complementary Medicine	1	13%

TABEL AP2.31: IT AND INFORMATION SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
10	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	2	7%
	Pub 51	Mathematical & computational Biology	1	4%
	Pub 36	Medical Informatics	1	4%
	Pub 27	Engineering; Optics;	2	4%
	Pub 10	Orthopedics; Rheumatology;	2	3%

TABEL AP2.32: CHEMICALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
20	Pub 35	Biotechnology applied microbiology; Food Science & Technology;	1	25%
	Pub 24	Nutrition & Dietetics; Food Science & Technology;	1	19%
	Pub 20	Biochemistry Molecular Biology; Biophysics;	3	15%
	Pub 49	Biophysics	4	15%
	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	1	14%

TABEL AP2.33: AGRICULTURE, FORESTRY AND FISHERY

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
6	Pub 22	Fisheries	2	7%
	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	1	5%
	Pub 6	Veterinary Sciences; Zoology;	1	5%
	Pub 53	Agriculture	3	3%
	Pub 48	Zoology	1	2%

TABEL AP2.34: MECHANICAL ENGINEERING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
21	Pub 39	Engineering; Instruments & Instrumentation;	3	19%
	Pub 50	Entomology	1	13%
	Pub 41	Energy & Fuels; Engineering;	5	10%
	Pub 14	Physics; Science & Technology - Other Topics; Optics	3	10%
	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	4	9%

TABEL AP2.35: PHARMACEUTICALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
43	Pub 21	Endocrinology & Metabolism; Physiology;	1	84%
	Pub 23	Allergy	6	79%
	Pub 25	Pharmacology & Pharmacy; Psychiatry;	2	67%
	Pub 5	Health Care Sciences & Services; Public, Environmental & Occupational Health;	2	61%
	Pub 37	Neurosciences & Neurology; Pharmacology & Pharmacy;	3	59%

TABEL AP2.36: METALS

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	2	13%
	Pub 41	Energy & Fuels; Engineering;	3	4%
	Pub 4	Chemistry; Engineering;	2	2%
	Pub 53	Agriculture	1	0%

TABEL AP2.37: OTHER MANUFACTURING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
1	Pub 7	Transplantation	1	3%

TABEL AP2.38: PLASTIC, GLASS AND CONCRETE

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
21	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	2	5%
	Pub 1	Biochemistry Molecular Biology; Life Sciences & Biomedicine - Other Topics; Cell Biology	2	5%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	1	5%
	Pub 47	Nursing	1	4%
	Pub 19	Microscopy	1	3%

TABEL AP2.39: OTHER BUSINESS SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
4	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	1	5%
	Pub 23	Allergy	1	0%
	Pub 20	Biochemistry Molecular Biology; Biophysics;	1	0%
	Pub 49	Biophysics	1	0%

TABEL AP2.40: CONSULTANCY AND ADVISORY SERVICES

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
30	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	13	91%
	Pub 4	Chemistry; Engineering;	1	62%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	2	38%
	Pub 14	Physics; Science & Technology - Other Topics; Optics	1	20%
	Pub 52	Mineralogy	3	17%

TABEL AP2.41: NATURAL RESSOURCE EXTRACTION

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
3	Pub 45	Engineering; Geology;	3	19%
	Pub 52	Mineralogy	1	4%
	Pub 41	Energy & Fuels; Engineering;	2	2%

TABEL AP2.42: TRANSPORT AND TRANSPORTATION EQUIPMENT

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
5	Pub 34	Materials Science; Metallurgy & Metallurgical Engineering;	1	6%
	Pub 41	Energy & Fuels; Engineering;	1	4%
	Pub 40	Electrochemistry; Materials Science;	1	3%
	Pub 4	Chemistry; Engineering;	2	2%
	Pub 53	Agriculture	1	1%

TABEL AP2.43: WOOD, PAPER AND PRINTING

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
3	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	1	4%
	Pub 4	Chemistry; Engineering;	1	2%
	Pub 53	Agriculture	1	1%

TABEL AP2.44: WATER AND WASTE

No. of core competences	core competence ID	Core competence description	No. of firms	Share of patents behind core competence
8	Pub 26	Engineering; Environmental Sciences & Ecology; Water Resources	3	18%
	Pub 32	Chemistry; Science & Technology - Other Topics; Materials Science	1	5%
	Pub 39	Engineering; Instruments & Instrumentation;	1	3%
	Pub 20	Biochemistry Molecular Biology; Biophysics;	1	1%
	Pub 49	Biophysics	1	1%

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